U.S. Coast Guard Research and Development Center

1082 Shennecossett Road, Groton, CT 06340-6096

Report No. CG-D-30-98

Rotating Arm Captive Model Tests of the U.S. Coast Guard Prototype 47-FT Motor Lifeboat

FINAL REPORT

OCTOBER 1998

Prepared for:

U.S. Department of Transportation
United States Coast Guard
Engineering Logistics Center
Baltimore, MD 21226-1792

19990104 052

DTIC QUALITY INSPECTED 8

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

The contents of this report reflect the views of the Coast Guard Research and Development Center. This report does not constitute a standard, specification, or regulation.

Marc B. Mandler, Ph.D.
Technical Director
United States Coast Guard
Research & Development Center
1082 Shennecossett Road
Groton, CT 06340-6096

1. Report No. CG-D-30-98	2. Government Accession Number	3. Recipient's Catalog No.
4. Title and Subtitle Rotating Arm Captive Model Tests of the U.S. Coast Guard Prototype 47-FT Motor Lifeboat		5. Report Date October 1998
		6. Performing Organization Code Project No. 9208.3.2 / UDI: 4
7. Author(s) Edward M. Lewandowski and Walter E. Klosinski		8. Performing Organization Report No. R&DC 18/98
9. Performing Organization Name and Address Davidson Laboratory Stevens Institute of Technology Castle Point Station Hoboken, NJ 07030	U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, CT 06340-6096	10. Work Unit No. (TRAIS)
		11. Contract or Grant No. DTCG32-92-P-E00798
12. Sponsoring Organization Name and Address U.S. Department of Transportation United States Coast Guard Engineering Logistics Center Baltimore, MD 21226-1792		13. Type of Report & Period Covered Final
		14. Sponsoring Agency Code U.S. Coast Guard Headquarters Engineering Logistics Center Baltimore, MD 21226-1792

15. Supplementary Notes

The R&D Center's technical point of contact is Mr. James White, 860-441-2734.

16. Abstract (MAXIMUM 200 WORDS)

The USCG prototype 47-FT Motor Lifeboat (MLB) experienced transient roll angles of as much as 40 degrees in a turn at 27 knots with 30 degrees of rudder. The prototype was modified to correct this problem, by moving the rudders to a vertical position, vice 15 degrees outboard angle. The tests reported on here were part of an effort to develop a computer simulation of this snap roll phenomenon. Captive rotating arm tests were conducted using a 1/9.032 scale model of the 47 FT MLB. The model was fully appended, with the propellers driven by an electric motor. Tests were conducted at two speeds, two turning radii, and a range of drift and roll angles. The results are presented in tabular and graphical form. Curves through the data were drawn using a computer plotting package which did not yield the equations for the curves drawn.

17. Key Words motor lifeboat, maneuvering, planing boats, rotating arm tests, stability.	18. Distribution Statement This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161

19. Security Class (This Report) UNCLASSIFIED	20. Security Class (This Page) UNCLASSIFIED	21. No of Pages	22. Price

Form DOT F 1700.7 (8/72) Reproduction of form and completed page is authorized.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in²	square inches	6.5	square centimeters	cm²
ft²	square feet	0.09	square meters	m²
yd²	square yards	0.8	square meters	m²
mi²	square miles	2.6	square kilometers	km²
	acres	0.4	hectares	ha
MASS (WEIGHT)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft³	cubic feet	0.03	cubic meters	m³
yd³	cubic yards	0.76	cubic meters	m³
TEMPERATURE (EXACT)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly).

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm²	square centimeters	0.16	square inches	in²
m²	square meters	1.2	square yards	yd²
km²	square kilometers	0.4	square miles	mi²
ha	hectares(10,000 m²)	2.5	acres	
MASS (WEIGHT)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m³	cubic meters	35	cubic feet	ft³
m³	cubic meters	1.3	cubic yards	yd³
TEMPERATURE (EXACT)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

NOMENCLATURE

b   beam at chine, ft

d   propeller diameter, ft

K   roll moment, lb-ft

L   length between perpendiculars, ft

M   pitch moment, lb-ft

N   yaw mment, lb-ft

n   propeller speed, rotations per sec

R   radius of turn, ft

V   velocity, fps

W   weight or displacement

WA   weted area, sq. ft.

X   axial force, lb

Y   lateral force, lb

Z   normal force, lb

δ rudder deflection, deg

$\emptyset$ roll angle, deg

τ trim angle, deg

β dift angle, deg

Dimensionless Coefficients

X'   Axial force coefficient, X/W

Y'   Side force coefficient, Y/W

K'   Roll moment coefficient, K/Wb

N'   Yaw moment coefficient, N/Wb

n'   Propeller speed coefficient, nd/V

WA'   Wetted area coefficient, Wa/b^2

EXECUTIVE SUMMARY

The prototype of the U.S. Coast Guard 47-FT Motor Lifeboat (MLB) experienced transient roll angles of as much as 40 degrees in a turn at 27 knots with 30 degrees of rudder angle. The objective of the tests reported on here was to obtain hydrodynamic force and moment data by conducting captive model tests on a rotating arm for various prototypical conditions. These data can be used in the future to develop a computer model of the phenomenon. This will require that the data, and the MLB motions, be represented by mathematical equations. The results of computer simulations of the MLB in turn can be used to gain an insight into what caused the snap roll phenomenon so that it can be avoided in future designs. This will save some of the money that is normally expended in attempting to correct maneuvering deficiencies in prototype boats by full-scale trial and error methods.

[BLANK]

INTRODUCTION

The prototype of the U.S. Coast Guard 47-FT Motor Lifeboat (MLB) experienced large transient roll angles of as much as 40 degrees in a turn at 27 knots with a 30-degree rudder angle. The objective of the tests reported here was to obtain hydrodynamic force and moment data needed to understand this snap roll phenomenon by conducting captive tests of a model of the MLB on a rotating arm.

MODEL

A 1/9.032-scale wooden model, previously used for the self-propelled free turning tests (reference 1), was used for the rotating arm tests. The internal combustion engine, which had propelled the model in the free turning tests, was removed and replaced by an electric motor, which drove the twin propellers through a gear train. Stock propellers (Davidson Lab #80, diameter = 0.258 ft) were used. RPM were set by an electronic control system mounted on the end of the rotating arm. The two rudders were adjustable, but were fixed at zero degrees relative to the centerline of the hull for most but not all of the tests. A lines drawing of the 47-FT MLB is given in Figure 1, which also lists principal particulars. Figure 2 shows the details of the rudders, which were mounted normal to bottom of the hull.

The model was towed free to trim and heave but was locked in yaw, roll, surge, and sway. The trim axis and the yaw axis intersected on the propeller shaft line at the longitudinal center of gravity (LCG). The model's deck was covered and sealed with clear lucite. An opening was left for attachment to the towing apparatus and to allow access to set the roll angle. This opening was then sealed by a thin rubber collar between the bottom of the balance and the deck.

Since a test program requirement was to measure wetted areas during these tests, underwater photographs were taken of each test run. To facilitate making these measurements, the hull bottom was painted white and striped at one-inch increments along both chines and the longitudinal centerline. Every fifth transverse line extended across the beam from chine to chine. Because the stagnation line across the hull bottom often extends from a chine to the transom in rotating arm

1

tests, the transom also had short lines placed across the beam at 0.2 beam intervals, from the longitudinal centerline (zero) to each chine (one).

APPARATUS AND INSTRUMENTATION

Tests were conducted in the Davidson Laboratory Rotating Arm Facility. The rotating arm basin is 75-ft square and 4.5 ft deep. A pitch and roll pivot box, with provision for setting trim and roll angles, was mounted in the model. For these tests, the model was free to trim but fixed in roll. The trim axis was located 2.22 ft above the baseline and 4.84 ft aft of midships. The roll axis was located 0.753 ft (1.0 in. model-scale) above the trim axis.

A five-component balance was employed in the tests. Drag, side-force, and roll and yaw moments were measured in these tests, as indicated in the sketch in Appendix D. A graduated plate above the balance was included for setting the drift angle, and the balance rotated with the model in yaw but not in roll or trim. Heave was measured at the trim pivot, and an inclinometer was fitted to assist in setting the roll angles. The five-component balance was attached to twin vertical heave poles in a standard free-to-heave apparatus, which included provision for counter-weighting. The free-to-heave apparatus was mounted on a standard testing carriage. The trim angle was measured using a rotary variable differential transformer on the trim axis, and the propeller speed was measured using a tachometer located on one of the propeller shafts. A trim stop was incorporated in the apparatus, preventing the model from trimming down more than -2 degrees.

Underwater color photographs (35 mm slides) were taken of each test run. The view, which was taken from directly underneath the hull looking up, included the run number and a side view of the hull, as well as the principal pressure area. The photographs provide a record of the flow conditions about the hull, as well as showing the wetted lengths. The complete set of color slides is an important supplement to this report. The pictures were taken through a mirror mounted at 45 degrees on the floor of the tank. The camera was mounted in a vertical surface-piercing underwater transparent box. Flash units on the floor of the tank were used to illuminate the model. The

2

rotating arm drive shaft is equipped with a shaft encoder that indicates the position of the arm, which was used to trigger the camera and flash units when the model passed over the mirror.

TEST PROCEDURE

After the apparatus was set up, the instrumentation was calibrated by applying known displacements to the motion transducers, and known loads and moments to the five component balance. Combinations of loads and moments were applied to the balance in both the positive and negative senses. During calibration the outputs from the transducers were fed to the on-line computer, where a least-squares linear regression analysis was performed. All the calibrations were linear and the rates were stored for use during data collection. The calibrations were checked daily by the application of deadweights applied at a compound angle so as to cause simultaneous deflections in all the transducers. The data acquisition and processing was carried out by the on-line Masscomp computer using a program package designed by Davidson Laboratory known as DAP5. This program digitizes analog signals from the instruments at 250 Hz, and records them on disk in digital form during the test run. After the run the processing programs are called upon to process the data according to user specified parameters.

The model was set up for test in the following sequence. With the model at zero trim, that is with the keel horizontal, and at zero roll, the drift angle was set by rotating the model in the horizontal plane, then the roll angle was set by rolling the model about its longitudinal axis. Zeroes were taken with the model in the air at the required drift and roll angles. The model was then lowered into the water, and a zero speed run was made to measure the hydrostatic forces and moments acting on the model. The propellers were then started, and the model was accelerated up to the required speed, data were acquired in the data trap by scanning all channels at 250 Hz, and the results were converted into engineering units and stored in the computer. An underwater photograph was taken at the end of the data trap, and the model was decelerated and returned for the next run. The rotating arm tests were run in the clockwise direction and the data trap was set up in the fourth quadrant. Speeds were computed from the time taken to travel through the data trap. Plots of the measured data were made at tankside to monitor the results. Air tare tests were run

3

with the model in the air on the rotating arm, covering the test ranges of speed, radius, yaw, and roll angle to determine the aerodynamic and centrifugal forces and moments. These forces and moments were later subtracted from the total forces and moments measured with the model in the water.

Water temperature in the basin was measured daily and a tabulation of these temperatures is included in Appendix E.

TEST PROGRAM

The model displacement for all tests was 55.42 lb, corresponding to a full-scale displacement of 42,000 lb in salt water at 59° F. Tests were conducted at radii of 32 ft and 15.67 ft. The radius of a turn is measured in the horizontal plane and refers to the radius at the tow point. These turning radii correspond to 6.74L and 3.30L where L is the boat length between perpendiculars.

All tests were run with the propellers set for the rate which was determined for straight-course operation at the given speed in Reference 1:

SPEED, knots	RPM (full-scale)	RPM(model)	n'
10	769	2310	1.767
27	1471	4420	1.253

where n' is a nondimensional propeller speed based on propeller diameter and model speed:

$$n' = nd/V$$

Here n is the propeller speed in revolutions per second, d is the propeller diameter, and V is the boat speed in feet per second. The required motor speed setting for this propeller speed was determined with the model running at zero drift and roll. Because the propeller speed varied slightly with drift and roll due to variations in loading (particularly at large roll angles where one propeller was not fully submerged) the actual RPM was measured and is reported in the data tables.

Twin rudders were mounted on the model for all tests. Except for the series of tests in which the rudder angles were varied the rudders were set at zero degrees.

The model was free to trim for all tests. The following test matrix was used for the tests at R/L = 6.74 and 3.30 with the rudder at 0 degrees:

SPEED, knots	ROLL, deg	DRIFT, deg
10	-5, 0, 5	-15 (5) 15
27	-35, -20 (10) 20, 35	-15 (5) 15

For the rudder tests at R/L = 6.74 and zero drift angle, the following test matrix was used:

SPEED, knots	ROLL, deg	DRIFT, deg
10	-20, 0, 20	-30, -20, 0, 20, 30
27	-20, 0, 20	-30, -20, 0, 20, 30

DATA PROCESSING

The test data were processed to meet several requirements. These include 1) a tabulation of the "raw" data on a day-by-day, run-by-run basis; 2) presentation of the data in a coordinate system with origin at the center of gravity; and 3) presentation of the data in non-dimensional form. There was also a requirement to illustrate the data reduction process, and to present the transformation equations from the balance coordinate system to the final coordinate system.

These requirements are met in the following manner. 1) Each run is given a unique sequence number, and therefore a listing of the run numbers and test conditions satisfies the need for a run by record. This is included in Appendix A which is the Chronological Run Directory. The run

5

numbers are assigned sequentially by the computer, and a "run" identifies a data-taking event which is not necessarily a run down the tank. Thus in Appendix A some run numbers have the prefix DZ which indicates that the data were taken at zero speed, while others are prefaced by DR which denotes a run taken for checking purposes. The raw data are taken to be the dimensional model data in "balance axes." The balance axes move with the model, have a horizontal and vertical orientation, and have their origin on the roll axis at the LCG; the x-axis is positive forward, the y-axis is positive to starboard, and the z-axis is positive downward. The data in balance axes, before removal of the air tares, is presented in Appendix B and represents the raw data. This Appendix also includes a tabulation of the results of the zero-speed tests which were mentioned under Procedure above.

To obtain hydrodynamic forces and moments, the air tare data were analyzed as described below, and the tares were subtracted from the raw data. Next, the data were transferred to "waterplane axes." These axes have the same orientation as the balance axes described above, but their origin is at the CG of the vessel. This is the most convenient reference frame for analysis and simulation as discussed in Reference 2. In this coordinate system, as in the balance axes system, the drift angle is measured relative to the velocity vector at the CG, positive to starboard; the roll angle is measured about a horizontal axis, positive starboard side down; and a positive rudder deflection corresponds to clockwise rotation of the rudder shaft looking downward from above. Model-scale data in waterplane axes are tabulated in Appendix C. Forces and moments were next normalized by division by the displacement and the product of displacement and beam, respectively (Please see the Nomenclature for the definitions of dimensionless coefficients). Dimensionless results are presented in Tables 1 - 4; each table corresponds to a particular speed and turning radius. Results of the rudder deflection tests are contained in Tables 5 and 6 for speeds of 10 and 27 knots, respectively.

The balance and waterplane coordinate systems and transformation equations are presented in Appendix D.

Air Tares

The first step in the data processing is to identify and remove the forces and moments due to centrifugal and aerodynamic forces. The "air tare" data were plotted and suitable equations identified to represent these data. A regression analysis of the "air tare" data taken with the model in the air was performed, and the resulting equations developed for the air tare forces and moments are given in Appendix D. As a check on these fits, the air tare data itself was corrected by subtracting the forces and moments given by these equations from the data, and examining the residuals. These were sufficiently small to show that a satisfactory fit had been obtained. These same equations were then applied to the data taken with the model in the water.

Wetted Area

The underwater pictures were used to record the wetted area of the hull. Due to the asymmetric attitude of the hull when rolled in a turn, it was necessary to read both the port and starboard wetted chine lengths, as well as the keel wetted length. In the cases where the chines were dry, because either the stagnation line crossed the transom or the flow separated before reaching the chine, the fraction of the beam at the transom was recorded. The wetted areas were calculated from the keel, chine, and transom wetted lengths observed in each run, together with the hull girths from chine to chine, and are tabulated in dimensionless form (normalized using the square of the beam) in Tables 7-12. Please see the Nomenclature for the definition of this dimensionless form. Model-scale dimensional values are included in Appendix B.

The heave and trim transducers were used to calculate the transom draft (TD) and the "static keel wetted length" (SKWL), which is the keel wetted length without allowing for wave rise. The dynamic keel wetted length from the underwater photographs may be correlated with the SKWL, which provides a means of fairing this data. The transom draft is defined as the draft of the keel at the transom relative to the still water surface. Both TD and SKWL are illustrated in the following sketch and included in the raw data tables presented in Appendix B.

7

Transom Draft

SKWL
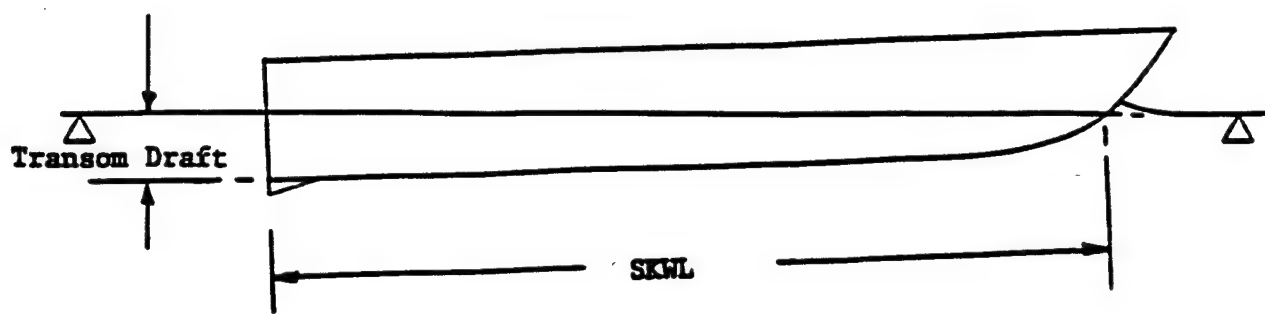
RESULTS AND DISCUSSION

Results for a speed of 27 knots at a turning radius to length ratio R/L of 6.74 are presented graphically on Figures 3-7, and for R/L = 3.30 on Figures 8-12. These figures show dimensionless force and moment coefficients and measured trim angle against drift angle with roll angle as a parameter. Roll moment is plotted against roll angle with drift angle as a parameter on Figures 14 and 15 which correspond to the two turning radii at 27 knots. Figures 16-20 show the force and moment coefficients and trim angle against drift angle with roll angle as a parameter, at a speed of 10 knots and R/L = 6.74; corresponding results for R/L = 3.30 are shown on Figures 21-25.

Figures 3-25 show that the side force, yaw moment and roll moment vary smoothly with drift angle, except at the combination of the maximum drift angle (±15°) with roll angles of ±35°. The underwater photographs show that in some of these combinations, the stagnation line along the uppermost side of the hull (i.e., port side at a roll angle of +35°) intersects the propeller and rudder. Figure 13 is a plot of the distance from the center of the propeller up to the undisturbed free surface level, calculated from the trim and roll angles and the "transom draft" reported in Appendix B. Results for roll angles of ±35° and -20° are shown. It can be seen that at a roll angle of -35°, the propeller centerline is above the free surface level at drift angles of -10° and -15°, and at a drift angle of 15° at 35° roll. Reference to Figure 3, for example, shows that these are the points which "fall away" from an essentially linear relationship of side force with drift angle. Thus the behavior of the forces and moments at these conditions is probably due to a loss of effectiveness of the uppermost propeller and rudder due to the proximity of the surface. The behavior of axial force is

consistent with this hypothesis. Figure 6 shows that while the axial force increases with drift angle after reaching a minimum at around 5° at a roll angle of -20°, there is a sharp decrease in axial force with increasing drift angles at a roll angle of -35°. This would be expected if a propeller is losing effectiveness at the latter combination.

Figures 7 and 12 show the behavior of the trim angle with variations in roll and drift. The figures show that as the drift and roll angles increase (which would occur as the boat enters a turn), the trim decreases, and that a large increase in trim would be observed if the boat somehow rolled outboard in the turn. This behavior may be induced by the vertical component of the total rudder force, which acts upward for roll angles into the turn and downward for roll angles out of the turn.

The behavior of roll moment with roll angle at constant drift angle is shown on Figures 14 and 15 for the two turning radii examined. A straight line is a good representation of the data at drift angles of 0° and -15°; however, at the 15° drift angle there is a region in which the roll moment decreases with decreasing roll angle. This occurs at the unlikely combination of the large positive drift angle with negative roll angles; however, such a combination would be possible as a result of a large roll disturbance which could be the result of a beam wave, for example. This is an indication that caution should be exercized when turning in waves.

The trends of side force and roll moment with drift and roll angles at a speed of 10 knots are similar to the behavior at 27 knots. However, the behavior of the yaw moment at 10 knots (Figure 22) is quite different than that at 27 knots (Figure 4). At 10 knots the yaw moment changes very little with increasing drift angle for positive drift angles (into the turn), and decreases with decreasing drift angle at negative drift angles. At 27 knots, the yaw moment consistently decreases with increasing drift angle. This would indicate that the hydrodynamic resistance to turning is less at 10 knots than at 27 knots, which is consistent with the observed behavior of the model in the free running tests (Reference 1).

The behavior of the force and moment coefficients and trim angle with rudder deflection is shown on Figures 26 - 31 for 27 knots, and on Figures 32 - 36 for 10 knots. The salient feature of these

plots is the sharp break which occurs (in most cases) above a rudder angle of 20° (recall that positive rudder angles would act to bring the boat <u>out</u> of the clockwise turn). This phenomenon is probably associated with stalling on at least one of the rudders. The break occurs at a lower rudder angle at 27 knots, at zero and negative roll angles; underwater photographs show that air is reaching the rudders in these conditions. It is noted that this reduction in rudder effectiveness does not occur at negative rudder angles, which would be associated with turns to starboard (which is the way the model was being towed).

Figure 30 shows the remarkable behavior of the trim angle with rudder deflection at 27 knots. Below a rudder angle of 20°, the increase of trim with increasing rudder deflection at a positive roll angle, and reduction of trim with increasing rudder angle at a negative roll angle, is consistent with the expected behavior of the vertical component of rudder force (upward at positive roll angles, downward for negative roll angles for a negative rudder angle as discussed above). However, in the extreme condition of a 30° rudder angle, the trim drops sharply at all roll angles to a negative value. Figure 31 shows that the draft at the transom also decreases sharply at the 30° rudder angle. The reason for this behavior is not clear; it occurs in the region of reduced rudder effectiveness discussed above, which makes it improbable that this is a direct rudder effect. The behavior of the trim of the boat with rudder deflection demonstrates that Figures 26 - 36 contain not only the direct effects of the rudder deflection on hydrodynamic forces and moments, but also indirect effects such as those due to trim changes of the hull.

The curves drawn through the data are the result of an automatic computer plotting routine which unfortunately does not yield mathematical equations for the curves.

From underwater photographs it was seen that under some conditions a considerable amount of "side wetting" of the hull occurred. The tabulated wetted areas include only the wetted bottom area.

CONCLUDING REMARKS

The results of these captive rotating-arm tests of the 47-FT MLB, together with the results of the free-running tests of the same model documented in Reference 1, constitute a valuable and unique database which can be used to obtain a deeper understanding of the behavior of the vessel in a turn. It is hoped that this understanding will lead to improved design procedures for planing craft with respect to maneuverability and stability.

Examination of the data obtained in this study has indicated several areas which merit further investigation. The turning performance of the vessel, for example, is strongly affected by speed. It would be of value to examine the behavior of hydrodynamic forces and moments with speed (at, say, 2 knot increments from 10 to 30 knots) at a limited number of roll-drift-radius combinations. Also, the effect of propeller speed should be better defined by conducting some tests at a range of RPM's. This is necessary because the characteristics of the electric motor differed from those of the internal combustion motor used in the free-running tests, both of which probably differ from the prototype motor characteristics. It would also be of interest to instrument a rudder and measure the rudder force directly during captive tests. Finally, zig-zag type tests should be conducted with the free-running model to determine if the bow-down tendency shown on Figure 30 is indicative of a serious problem in the event that the operator attempts to reverse course rapidly.

REFERENCES

1. Lewandowski, E. M., "Free Running Model Turning Tests of the U. S. Coast Guard 47 FT Motor Life Boat," Davidson Laboratory Technical Report No. 2690, August 1993. (USCG Report No. CG-D-6-95)

2. Lewandowski, E. M., "Directional Stability Tests and Maneuvering Predictions for a High-Speed Patrol Boat," Proceedings, 23rd American Towing Tank Conference, June 1992.

TABLE 1   Test Data in Waterplane Axes, Nondimensional
Speed: 10 knots   R/L: 6.74

Run no	Roll deg	Drift deg	Trim deg	X'	Y'	K'	N'	n'
83	-5	-15	2.05	0.0081	-0.1631	0.0457	-0.0874	1.774
89	-5	-10	2.04	0.0175	-0.0941	0.0422	-0.0501	1.771
88	-5	-5	2.15	0.0116	-0.0414	0.0345	-0.0302	1.780
50	-5	0	2.23	0.0045	0.0086	0.0217	-0.0281	1.766
81	-5	0	2.33	0.0048	0.0106	0.0250	-0.0305	1.767
51	-5	5	2.50	-0.0018	0.0585	0.0120	-0.0343	1.762
87	-5	5	2.43	0.0079	0.0577	0.0132	-0.0357	1.776
52	-5	10	2.70	-0.0012	0.1090	0.0031	-0.0344	1.762
78	-5	10	2.72	-0.0042	0.1112	0.0056	-0.0356	1.727
79	-5	10	2.71	0.0006	0.1122	0.0052	-0.0362	1.758
53	-5	15	2.88	0.0003	0.1674	-0.0052	-0.0293	1.759
80	-5	15	2.93	0.0041	0.1712	-0.0048	-0.0321	1.764
38	0	-15	1.68	0.0201	-0.1507	0.0165	-0.0996	1.766
105	0	-15	1.73	0.0173	-0.1553	0.0208	-0.1075	1.776
37	0	-10	1.88	0.0150	-0.0867	0.0115	-0.0632	1.754
104	0	-10	1.93	0.0132	-0.0859	0.0172	-0.0680	1.769
36	0	-5	2.02	0.0080	-0.0376	0.0043	-0.0429	1.750
103	0	-5	2.02	0.0076	-0.0314	0.0103	-0.0452	1.768
99	0	0	2.15	0.0063	0.0201	0.0013	-0.0415	1.775
33	0	5	2.30	0.0101	0.0733	-0.0140	-0.0472	1.759
100	0	5	2.40	0.0043	0.0707	-0.0091	-0.0479	1.776
34	0	10	2.64	0.0044	0.1164	-0.0227	-0.0466	1.754
101	0	10	2.77	-0.0003	0.1234	-0.0171	-0.0494	1.771
35	0	15	2.82	0.0070	0.1717	-0.0288	-0.0392	1.751
102	0	15	2.84	0.0068	0.1818	-0.0242	-0.0416	1.761
47	5	-15	1.48	0.0173	-0.1321	-0.0040	-0.1102	1.768
93	5	-15	1.55	0.0160	-0.1387	-0.0026	-0.1213	1.767
46	5	-10	1.74	0.0114	-0.0709	-0.0096	-0.0763	1.769
94	5	-10	1.79	0.0112	-0.0715	-0.0075	-0.0801	1.764
45	5	-5	1.99	0.0040	-0.0201	-0.0167	-0.0567	1.777
97	5	-5	2.03	0.0037	-0.0174	-0.0143	-0.0577	1.767
40	5	0	2.14	0.0027	0.0335	-0.0254	-0.0534	1.771
91	5	0	2.15	0.0037	0.0363	-0.0237	-0.0547	1.770
41	5	5	2.40	0.0025	0.0842	-0.0350	-0.0592	1.778
96	5	5	2.51	-0.0009	0.0876	-0.0330	-0.0606	1.770
43	5	10	2.68	0.0024	0.1311	-0.0442	-0.0605	1.771
95	5	10	2.78	-0.0008	0.1385	-0.0417	-0.0620	1.770
44	5	15	2.94	0.0048	0.1903	-0.0485	-0.0558	1.766
92	5	15	3.03	0.0034	0.1982	-0.0475	-0.0571	1.764

TABLE 2   Test Data in Waterplane Axes, Nondimensional
Speed: 27 knots R/L: 6.74

Run no	Roll deg	Drift deg	Trim deg	X'	Y'	K'	N'	n'
145	-35	-15	2.56	0.0022	-0.5360	0.1329	0.2145	1.246
251	-35	-15	2.77	0.0031	-0.5586	0.1398	0.2176	1.268
250	-35	-10	4.49	-0.0023	-0.4984	0.1294	0.1581	1.262
252	-35	-7	5.78	-0.0021	-0.6456	0.1041	0.0825	1.248
249	-35	-5	6.61	-0.0225	-0.5916	0.0998	0.0798	1.248
226	-35	0	7.88	-0.0456	-0.2972	0.0806	-0.0051	1.231
245	-35	0	7.90	-0.0472	-0.3437	0.0806	0.0185	1.249
246	-35	5	9.29	-0.0654	-0.1110	0.0488	-0.0482	1.251
247	-35	10	11.29	-0.1514	0.0684	0.0604	-0.0534	1.260
227	-35	15	13.67	-0.1702	0.2911	0.0306	-0.1322	1.252
248	-35	15	13.61	-0.1682	0.2779	0.0273	-0.1364	1.264
220	-20	-15	3.00	0.0904	-0.6205	0.1042	0.2125	1.234
219	-20	-10	3.78	0.0541	-0.4283	0.0858	0.1411	1.236
218	-20	-5	4.70	0.0276	-0.2448	0.0652	0.0560	1.233
214	-20	0	5.65	0.0042	-0.0716	0.0447	-0.0401	1.226
215	-20	5	6.90	-0.0270	0.1016	0.0164	-0.1224	1.224
216	-20	10	8.09	-0.0157	0.3479	-0.0284	-0.2483	1.229
217	-20	15	9.54	0.0064	0.5853	-0.0746	-0.3609	1.226
221	-20	15	9.65	0.0066	0.5935	-0.0745	-0.3697	1.231
201	-10	-15	3.50	0.0715	-0.6956	0.0568	0.1824	1.235
210	-10	-15	3.42	0.0760	-0.6849	0.0570	0.1768	1.238
200	-10	-10	3.61	0.0435	-0.4479	0.0451	0.0971	1.239
199	-10	-5	3.96	0.0247	-0.2116	0.0321	0.0198	1.238
195	-10	0	4.54	0.0163	-0.0004	0.0150	-0.0574	1.235
206	-10	0	4.55	0.0174	0.0054	0.0163	-0.0579	1.233
196	-10	5	5.40	0.0028	0.1934	-0.0059	-0.1393	1.235
207	-10	5	5.41	0.0007	0.1963	-0.0040	-0.1400	1.233
197	-10	10	6.69	0.0013	0.4179	-0.0372	-0.2699	1.232
208	-10	10	6.71	0.0016	0.4164	-0.0354	-0.2677	1.231
198	-10	15	8.15	0.0335	0.6840	-0.0790	-0.4412	1.231
202	-10	15	8.20	0.0303	0.6860	-0.0772	-0.4409	1.231
209	-10	15	8.16	0.0326	0.6874	-0.0764	-0.4399	1.228
118	0	-15	4.69	0.0484	-0.5480	0.0176	0.1299	1.269
117	0	-10	3.98	0.0354	-0.3615	0.0072	0.0285	1.262
115	0	-5	3.59	0.0372	-0.1544	-0.0059	-0.0531	1.273
116	0	-5	3.67	0.0204	-0.1515	-0.0061	-0.0560	1.256
110	0	0	3.56	0.0184	0.0697	-0.0221	-0.1275	1.255
129	0	0	3.51	0.0123	0.0724	-0.0216	-0.1251	1.239
130	0	0	3.60	0.0266	0.0754	-0.0222	-0.1249	1.256
133	0	0	3.58	0.0211	0.0751	-0.0222	-0.1259	1.253
178	0	0	3.79	0.0192	0.0688	-0.0220	-0.1209	1.244
180	0	0	3.81	0.0257	0.0662	-0.0223	-0.1202	1.249
242	0	0	3.82	0.0229	0.0677	-0.0194	-0.1188	1.250
111	0	5	3.82	0.0236	0.2867	-0.0400	-0.1970	1.253
112	0	10	4.46	0.0275	0.4953	-0.0529	-0.2732	1.245
113	0	15	5.48	0.0485	0.7109	-0.0695	-0.3917	1.237
114	0	15	5.36	0.0702	0.7110	-0.0721	-0.3956	1.245

13

TABLE 2 (Continued)   Test Data in Waterplane Axes, Nondimensional
Speed: 27 knots   R/L: 6.74

Run no	Roll deg	Drift deg	Trim deg	X'	Y'	K'	N'	n'
131	0	15	5.47	0.0631	0.7131	-0.0713	-0.3959	1.242
136	10	-15	5.97	0.0143	-0.4590	0.0154	0.1473	1.252
155	10	-15	6.11	0.0094	-0.4817	0.0122	0.1606	1.250
153	10	-10	5.06	-0.0115	-0.2471	-0.0194	-0.0123	1.249
152	10	-5	4.02	-0.0019	-0.0664	-0.0426	-0.1139	1.248
148	10	0	3.47	0.0455	0.1272	-0.0612	-0.1779	1.264
154	10	0	3.47	0.0076	0.1231	-0.0596	-0.1803	1.237
149	10	5	3.30	0.0219	0.3497	-0.0771	-0.2555	1.228
150	10	10	3.45	0.0479	0.5899	-0.0906	-0.3320	1.232
151	10	15	3.57	0.0852	0.8339	-0.0954	-0.4144	1.225
139	20	-15	7.82	-0.0911	-0.3309	-0.0443	0.0695	1.243
165	20	-15	8.36	-0.0827	-0.3570	-0.0194	0.1057	1.250
257	20	-15	8.30	-0.0963	-0.3294	-0.0455	0.0535	1.268
164	20	-10	5.93	-0.0378	-0.1953	-0.0317	-0.0287	1.259
163	20	-5	4.99	-0.0346	0.0397	-0.0636	-0.1172	1.243
159	20	0	3.88	-0.0169	0.2375	-0.0856	-0.1932	1.238
255	20	0	3.98	-0.0126	0.2337	-0.0887	-0.1920	1.253
160	20	5	3.34	0.0210	0.3980	-0.1032	-0.2784	1.237
161	20	10	2.84	0.0475	0.5953	-0.1192	-0.3521	1.235
162	20	15	2.48	0.0824	0.8330	-0.1319	-0.4240	1.223
256	20	15	2.44	0.0895	0.8148	-0.1352	-0.4171	1.248
142	35	-15	9.82	-0.1474	-0.2172	-0.0603	-0.0404	1.237
190	35	-15	10.26	-0.1359	-0.2372	-0.0636	-0.0140	1.241
189	35	-10	8.28	-0.1336	-0.0468	-0.0934	-0.1008	1.241
188	35	-5	5.96	-0.0733	0.1339	-0.1105	-0.1796	1.243
184	35	0	5.13	-0.0384	0.3737	-0.1249	-0.2133	1.240
185	35	5	4.91	-0.0302	0.7161	-0.1450	-0.2935	1.242
191	35	5	4.54	-0.0276	0.6702	-0.1419	-0.2849	1.226
186	35	10	2.94	0.0292	0.8605	-0.1404	-0.2841	1.240
187	35	15	1.13	0.0525	0.6742	-0.1407	-0.3165	1.234

TABLE 3   Test Data in Waterplane Axes, Nondimensional
Speed: 10 knots   R/L: 3.30

Run no	Roll deg	Drift deg	Trim deg	X'	Y'	K'	N'	n'
414	-5	-15	1.44	0.0313	-0.1495	0.0508	-0.1543	1.779
413	-5	-10	1.76	0.0367	-0.0723	0.0443	-0.1128	1.778
412	-5	-5	2.08	0.0174	-0.0181	0.0364	-0.0736	1.782
408	-5	0	2.39	0.0135	0.0365	0.0265	-0.0642	1.784
409	-5	5	2.71	0.0077	0.0882	0.0158	-0.0670	1.784
410	-5	10	2.99	0.0094	0.1376	0.0054	-0.0712	1.781
411	-5	15	3.27	0.0144	0.2009	-0.0037	-0.0711	1.779
415	-5	15	3.29	0.0130	0.1962	-0.0029	-0.0698	1.779
386	0	-15	1.17	0.0230	-0.1122	0.0306	-0.1514	1.787
385	0	-10	1.51	0.0386	-0.0566	0.0201	-0.1263	1.793
384	0	-5	1.90	0.0173	-0.0056	0.0134	-0.0890	1.779
379	0	0	2.20	0.0082	0.0432	0.0047	-0.0765	1.753
387	0	0	2.27	0.0097	0.0441	0.0046	-0.0791	1.784
381	0	5	2.65	0.0072	0.1008	-0.0062	-0.0799	1.780
382	0	10	2.92	0.0110	0.1502	-0.0154	-0.0840	1.783
383	0	15	3.23	0.0160	0.2086	-0.0217	-0.0832	1.781
403	5	-15	1.01	0.0226	-0.1020	0.0071	-0.1603	1.790
402	5	-10	1.40	0.0329	-0.0474	-0.0055	-0.1373	1.790
401	5	-5	1.74	0.0143	0.0038	-0.0127	-0.1023	1.782
391	5	0	2.10	0.0109	0.0545	-0.0214	-0.0902	1.784
404	5	0	2.16	0.0086	0.0590	-0.0212	-0.0923	1.785
392	5	5	2.56	0.0103	0.1115	-0.0318	-0.0906	1.794
399	5	10	2.93	0.0091	0.1654	-0.0386	-0.0964	1.780
400	5	15	3.24	0.0146	0.2220	-0.0453	-0.0978	1.784

Run no	Roll deg	Drift deg	Trim deg	X'	Y'	K'	N'	n'
529	-35	-15	4.12	-0.0199	-0.5345	0.1474	0.1731	1.276
528	-35	-10	5.72	-0.0380	-0.4360	0.1299	0.1109	1.270
530	-35	-10	5.73	-0.0062	-0.4407	0.1278	0.0941	1.273
527	-35	-5	8.82	-0.0710	-0.5877	0.1186	0.0127	1.251
523	-35	0	9.50	-0.0617	-0.2774	0.0684	-0.0628	1.252
532	-35	0	8.97	-0.0415	-0.2288	0.0652	-0.0820	1.260
524	-35	5	10.31	-0.0746	0.0198	0.0344	-0.1416	1.253
525	-35	10	12.55	-0.1015	0.1964	0.0292	-0.1760	1.266
526	-35	15	14.08	-0.1171	0.4073	-0.0030	-0.2422	1.270
531	-35	15	14.10	-0.1128	0.4128	-0.0056	-0.2461	1.278
515	-20	-15	3.58	0.0730	-0.5335	0.0967	0.1465	1.247
514	-20	-10	4.60	0.0454	-0.3544	0.0746	0.0725	1.251
513	-20	-5	5.57	0.0183	-0.1656	0.0522	-0.0171	1.249
509	-20	0	6.79	0.0007	-0.0010	0.0293	-0.1104	1.248
510	-20	5	8.09	-0.0183	0.1999	-0.0060	-0.2200	1.250
511	-20	10	9.51	0.0034	0.4465	-0.0566	-0.3577	1.246
512	20	15	10.60	0.0386	0.6704	-0.1077	-0.4675	1.247
516	-20	15	10.47	0.0350	0.6631	-0.1049	-0.4596	1.244
503	-10	-15	3.41	0.0670	-0.6053	0.0497	0.0684	1.259
502	-10	-10	3.04	0.0629	-0.3172	0.0346	-0.0179	1.253
501	-10	-5	3.22	0.0567	-0.0806	0.0144	-0.0788	1.250
483	-10	0	5.29	0.0051	0.0801	-0.0001	-0.1381	1.248
504	-10	0	4.49	0.0399	0.0942	-0.0046	-0.1428	1.253
498	-10	5	6.29	-0.0014	0.2771	-0.0253	-0.2258	1.249
499	-10	10	7.65	0.0131	0.5102	-0.0580	-0.3639	1.248
484	-10	15	9.29	0.0584	0.7896	-0.1056	-0.5537	1.244
500	-10	15	9.31	0.0590	0.7938	-0.1067	-0.5610	1.247
441	0	-15	4.56	0.0421	-0.4988	0.0028	0.0232	1.261
440	0	-10	4.11	0.0297	-0.2974	-0.0025	-0.0662	1.255
439	0	-5	3.92	0.0173	-0.0788	-0.0165	-0.1410	1.250
429	0	0	3.98	0.0199	0.1451	-0.0362	-0.2090	1.245
431	0	0	4.05	0.0496	0.1527	-0.0384	-0.2132	1.274
432	0	0	4.02	0.0419	0.1472	-0.0357	-0.2110	1.257
433	0	0	3.94	0.0388	0.1422	-0.0372	-0.2128	1.257
434	0	0	4.05	0.0307	0.1436	-0.0373	-0.2104	1.249
436	0	5	4.40	0.0294	0.3731	-0.0528	-0.2849	1.251
437	0	10	5.17	0.0486	0.5726	-0.0658	-0.3624	1.247
438	0	15	6.48	0.0761	0.8164	-0.0883	-0.4970	1.240
442	0	15	6.43	0.0795	0.8068	-0.0872	-0.4912	1.246
454	10	-15	6.34	-0.0221	-0.3875	-0.0220	0.0558	1.254
453	10	-10	4.65	-0.0135	-0.2021	-0.0355	-0.1445	1.256
452	10	-5	3.57	-0.0019	-0.0350	-0.0495	-0.2246	1.251
446	10	0	3.29	0.0188	0.1895	-0.0733	-0.2969	1.252
447	10	5	3.30	0.0329	0.4274	-0.0883	-0.3588	1.249
455	10	5	3.34	0.0305	0.4188	-0.0867	-0.3542	1.250
448	10	10	3.38	0.0724	0.6564	-0.0962	-0.4248	1.250
449	10	15	3.85	0.1212	0.9186	-0.1008	-0.5138	1.253

TABLE 4 (Continued)   Test Data in Waterplane Axes, Nondimensional
Speed: 27 knots   R/L: 3.30

Run no	Roll deg	Drift deg	Trim deg	X'	Y'	K'	N'	n'
464	20	-15	7.49	-0.1125	-0.2754	-0.0696	-0.0328	1.264
465	20	-15	7.51	-0.1143	-0.2839	-0.0705	-0.0325	1.259
463	20	-10	5.39	-0.0311	-0.1335	-0.0506	-0.1256	1.259
462	20	-5	3.85	-0.0241	0.0330	-0.0774	-0.2491	1.257
458	20	0	3.10	0.0026	0.2569	-0.1017	-0.3152	1.260
459	20	5	2.76	0.0256	0.4500	-0.1181	-0.3702	1.247
460	20	10	2.34	0.0690	0.6603	-0.1285	-0.4464	1.249
461	20	15	1.98	0.1205	0.8829	-0.1353	-0.5013	1.243
475	35	-15	7.44	-0.1343	-0.3085	-0.0981	-0.1730	1.261
474	35	-10	5.75	-0.1289	-0.0906	-0.1204	-0.2461	1.255
476	35	-10	5.75	-0.1306	-0.0879	-0.1225	-0.2613	1.256
473	35	-5	3.90	-0.0886	0.0945	-0.1216	-0.3101	1.264
468	35	0	3.26	-0.0564	0.3284	-0.1375	-0.3363	1.253
469	35	0	3.32	-0.0480	0.3345	-0.1386	-0.3342	1.261
470	35	5	3.00	-0.0107	0.6402	-0.1505	-0.3745	1.250
471	35	10	1.72	0.0362	0.8559	-0.1444	-0.3699	1.249
472	35	15	.47	0.0969	1.0074	-0.1351	-0.3380	1.250

TABLE 5 Test Data in Waterplane Axes, Nondimensional
Speed: 10 knots R/L: 6.74 Drift Angle: 0 deg
Rudder Deflection Tests

Run no	Roll deg	Rudder deg	Trim deg	X'	Y'	K'	N'	n'
322	-20	-30	3.35	-0.0363	-0.1134	0.1150	0.0917	1.769
321	-20	-20	3.33	-0.0192	-0.0932	0.1035	0.0683	1.772
320	-20	0	3.35	-0.0120	-0.0241	0.0700	-0.0045	1.767
323	-20	0	3.29	-0.0093	-0.0240	0.0700	-0.0046	1.780
319	-20	20	3.32	-0.0264	0.0395	0.0392	-0.0690	1.767
318	-20	30	3.28	-0.0378	0.0238	0.0443	-0.0535	1.773
306	0	-30	2.49	-0.0300	-0.0915	0.0465	0.0725	1.772
305	0	-20	2.36	-0.0047	-0.0610	0.0337	0.0406	1.781
301	0	0	2.18	0.0119	0.0204	0.0022	-0.0438	1.784
302	0	0	2.22	0.0091	0.0200	0.0021	-0.0439	1.773
303	0	20	2.41	-0.0111	0.0918	-0.0267	-0.1202	1.770
304	0	30	2.30	-0.0336	0.0865	-0.0233	-0.1147	1.767
309	20	-30	2.91	-0.0399	-0.0414	-0.0238	0.0384	1.772
310	20	-20	3.01	-0.0273	-0.0080	-0.0386	0.0055	1.773
311	20	0	2.63	-0.0087	0.0692	-0.0750	-0.0782	1.770
312	20	20	2.57	-0.0242	0.1324	-0.1040	-0.1476	1.771
313	20	30	1.92	-0.0199	0.0846	-0.0775	-0.1008	1.775
314	20	30	1.79	-0.0185	0.0857	-0.0771	-0.1020	1.772

18

TABLE 6   Test Data in Waterplane Axes, Nondimensional
Speed: 27 knots R/L: 6.74 Drift Angle: 0 deg
Rudder Deflection Tests

Run no	Roll deg	Rudder deg	Trim deg	X'	Y'	K'	N'	n'
287	-20	-30	6.34	-0.1133	-0.4987	0.2583	0.3796	1.234
286	-20	-20	6.20	-0.0527	-0.4119	0.2096	0.2883	1.238
283	-20	0	5.61	0.0076	-0.0884	0.0502	-0.0304	1.242
288	-20	10	5.40	0.0069	0.1034	-0.0408	-0.2167	1.233
284	-20	20	4.39	-0.0211	0.0323	-0.0372	-0.1406	1.242
285	-20	30	-1.47	-0.1153	0.0005	0.0315	-0.0550	1.255
265	0	-30	3.74	-0.0812	-0.3612	0.1780	0.3471	1.256
262	0	-20	3.79	-0.0272	-0.2771	0.1360	0.2520	1.257
264	0	-20	3.71	-0.0223	-0.2550	0.1268	0.2290	1.252
261	0	0	3.83	0.0188	0.0632	-0.0189	-0.1169	1.255
263	0	0	3.84	0.0222	0.0846	-0.0275	-0.1366	1.257
269	0	10	4.16	-0.0014	0.2409	-0.1045	-0.3093	1.250
266	0	20	2.91	-0.0173	0.1667	-0.0993	-0.2699	1.249
268	0	30	-2.43*	-0.0927	0.0108	-0.0071	-0.3922	1.252
279	20	-30	3.18	-0.0779	-0.2263	0.1147	0.2672	1.247
278	20	-20	3.34	-0.0290	-0.1039	0.0616	0.1456	1.252
274	20	0	4.14	-0.0202	0.2432	-0.0904	-0.1965	1.258
273	20	10	4.55	-0.0476	0.4437	-0.1788	-0.3930	1.254
276	20	20	4.76	-0.0920	0.5861	-0.2469	-0.5457	1.251
277	20	30	-1.92*	-0.1223	-0.0621	-0.0647	-0.5392	1.250

* Model on trim stop.

TABLE 7   Nondimensional Wetted Area Data
Speed: 10 knots   R/L: 6.74

Run no	Roll deg	Drift deg	WA' stbd	WA' port	WA' total
83	-5	-15	0.35	1.17	1.52
71	-5	-10	0.88	1.17	2.05
89	-5	-10	1.24	1.16	2.40
70	-5	-5	0.92	1.17	2.08
88	-5	-5	0.92	1.17	2.08
50	-5	0	1.26	1.26	2.53
65	-5	0	0.96	1.17	2.13
81	-5	0	0.93	1.17	2.10
51	-5	5	0.93	1.24	2.16
66	-5	5	0.92	1.23	2.14
87	-5	5	0.92	1.25	2.17
52	-5	10	0.96	1.23	2.19
68	-5	10	0.93	1.21	2.14
78	-5	10	0.94	1.21	2.16
79	-5	10	0.94	1.22	2.16
53	-5	15	0.97	1.26	2.24
69	-5	15	0.97	1.24	2.21
80	-5	15	0.99	1.23	2.21
105	0	-15	1.30	1.14	2.43
104	0	-10	1.29	1.12	2.41
103	0	-5	1.27	1.09	2.36
99	0	0	1.05	1.09	2.15
100	0	5	1.05	1.26	2.32
101	0	10	1.05	1.26	2.32
102	0	15	1.07	1.28	2.35
47	5	-15	1.31	1.04	2.35
93	5	-15	1.32	1.06	2.38
46	5	-10	1.30	1.03	2.33
94	5	-10	1.30	1.03	2.33
97	5	-5	1.30	0.97	2.27
91	5	0	1.29	0.97	2.26
96	5	5	1.29	0.96	2.25
95	5	10	1.14	0.99	2.14
92	5	15	1.16	1.25	2.41

TABLE 8   Nondimensional Wetted Area Data
            Speed: 27 knots   R/L: 6.74

Run no	Roll deg	Drift deg	WA' stbd	WA' port	WA' total
145	-35	-15	0.17	0.94	1.11
251	-35	-15	0.17	0.94	1.11
250	-35	-10	0.15	0.88	1.03
252	-35	-7	0.36	0.95	1.31
249	-35	-5	0.35	0.95	1.30
226	-35	0	0.25	0.90	1.15
245	-35	0	0.25	0.90	1.15
246	-35	5	0.27	0.87	1.13
247	-35	10	0.18	0.81	0.99
227	-35	15	0.13	0.76	0.89
248	-35	15	0.07	0.76	0.83
220	-20	-15	0.51	1.05	1.56
219	-20	-10	0.51	1.04	1.56
218	-20	-5	0.58	0.98	1.56
215	-20	5	0.52	0.89	1.42
216	-20	10	0.51	0.88	1.39
217	-20	15	0.22	0.85	1.07
221	-20	15	0.00	0.84	0.84
201	-10	-15	0.79	0.96	1.76
200	-10	-10	0.82	0.96	1.79
199	-10	-5	0.82	0.99	1.81
195	-10	0	0.87	0.76	1.63
196	-10	5	0.77	0.96	1.73
197	-10	10	0.69	0.88	1.57
198	-10	15	0.64	0.83	1.47
118	0	-15	0.89	0.88	1.78
117	0	-10	0.95	0.94	1.89
115	0	-5	0.96	0.99	1.95
116	0	-5	0.97	0.97	1.95
109	0	0	0.97	0.99	1.96
110	0	0	0.99	0.97	1.95
129	0	0	0.99	0.95	1.94
130	0	0	0.99	0.99	1.98
133	0	0	0.99	0.97	1.95
178	0	0	0.96	0.95	1.91
242	0	0	0.99	0.97	1.96
111	0	5	0.95	0.96	1.91
112	0	10	0.94	0.96	1.90
113	0	15	0.87	0.86	1.73
114	0	15	0.87	0.91	1.78
131	0	15	0.88	0.88	1.76
136	10	-15	0.58	0.93	1.51
155	10	-15	0.90	0.69	1.59
153	10	-10	0.88	0.77	1.65
152	10	-5	1.04	0.82	1.86
148	10	0	1.08	0.85	1.93

21

TABLE 8 (Continued)   Nondimensional Wetted Area Data
Speed: 27 knots   R/L: 6.74

Run no	Roll deg	Drift deg	WA' stbd	WA' port	WA' total
154	10	0	1.09	0.88	1.97
149	10	5	0.99	0.85	1.84
150	10	10	0.99	0.87	1.85
151	10	15	0.97	0.87	1.84
165	20	-15	0.85	0.17	1.02
257	20	-15	0.85	0.17	1.02
164	20	-10	1.00	0.42	1.42
163	20	-5	1.10	0.52	1.62
159	20	0	1.10	0.73	1.84
255	20	0	1.11	0.73	1.84
160	20	5	1.11	0.73	1.84
161	20	10	1.02	0.76	1.79
162	20	15	1.02	0.69	1.71
256	20	15	1.05	0.73	1.78
142	35	-15	0.85	0.15	1.00
190	35	-15	0.87	0.12	0.98
189	35	-10	0.94	0.09	1.03
188	35	-5	1.02	0.20	1.22
184	35	0	1.06	0.30	1.37
185	35	5	1.11	0.44	1.54
191	35	5	1.12	0.33	1.45
186	35	10	1.17	0.35	1.52
187	35	15	1.14	0.29	1.43

22

TABLE 9   Nondimensional Wetted Area Data
Speed: 10 knots   R/L: 3.30

Run no	Roll deg	Drift deg	WA' stbd	WA' port	WA' total
414	-5	-15	1.34	1.21	2.54
413	-5	-10	1.26	1.19	2.45
412	-5	-5	1.14	1.19	2.32
408	-5	0	1.26	1.24	2.50
409	-5	5	1.14	1.15	2.29
410	-5	10	0.82	1.25	2.08
411	-5	15	0.84	1.27	2.11
415	-5	15	0.84	1.26	2.10
386	0	-15	1.25	1.12	2.37
385	0	-10	1.27	1.15	2.42
384	0	-5	1.27	1.14	2.41
379	0	0	1.26	1.12	2.39
387	0	0	1.26	1.12	2.39
381	0	5	1.25	1.14	2.39
382	0	10	1.04	1.25	2.29
383	0	15	1.05	1.26	2.31
403	5	-15	0.85	1.08	1.93
402	5	-10	1.27	1.07	2.34
401	5	-5	1.30	1.06	2.36
391	5	0	1.28	1.05	2.33
404	5	0	1.27	1.02	2.29
392	5	5	1.27	1.05	2.33
399	5	10	1.26	1.08	2.34
400	5	15	1.12	1.23	2.36

TABLE 10   Nondimensional Wetted Area Data
Speed: 27 knots   R/L: 3.30

Run no	Roll deg	Drift deg	WA' stbd	WA' port	WA' total
529	-35	-15	0.19	0.89	1.08
528	-35	-10	0.19	0.88	1.07
530	-35	-10	0.18	0.87	1.05
527	-35	-5	0.25	0.90	1.15
523	-35	0	0.27	0.87	1.13
532	-35	0	0.23	0.85	1.08
524	-35	5	0.22	0.84	1.06
525	-35	10	0.17	0.77	0.94
526	-35	15	0.13	0.75	0.88
531	-35	15	0.13	0.75	0.88
515	-20	-15	0.50	0.93	1.44
514	-20	-10	0.59	0.91	1.49
513	-20	-5	0.56	0.87	1.43
509	-20	0	0.58	0.88	1.46
510	-20	5	0.53	0.87	1.39
511	-20	10	0.47	0.80	1.27
512	-20	15	0.30	0.76	1.06
516	-20	15	0.41	0.77	1.18
503	-10	-15	0.84	0.89	1.73
502	-10	-10	0.79	0.87	1.66
501	-10	-5	0.78	0.95	1.73
483	-10	0	0.79	0.97	1.76
504	-10	0	0.77	0.91	1.68
498	-10	5	0.72	0.89	1.61
499	-10	10	0.68	0.84	1.52
484	-10	15	0.62	0.75	1.37
500	-10	15	0.60	0.79	1.38
441	0	-15	0.92	0.91	1.83
440	0	-10	0.94	0.94	1.87
439	0	-5	0.97	0.96	1.94
429	0	0	0.97	0.97	1.95
430	0	0	0.95	0.95	1.90
431	0	0	0.95	0.95	1.90
436	0	5	1.01	1.01	2.02
437	0	10	0.87	0.89	1.76
438	0	15	0.82	0.83	1.64
442	0	15	0.80	0.82	1.62
454	10	-15	0.94	0.68	1.63
453	10	-10	1.02	0.76	1.78
452	10	-5	1.07	0.84	1.91
446	10	0	1.08	0.92	2.00
447	10	5	1.07	0.91	1.98
455	10	5	1.07	0.89	1.96
448	10	10	1.01	0.87	1.88
449	10	15	0.97	0.84	1.81

TABLE 10 (Continued) Nondimensional Wetted Area Data
Speed: 27 knots   R/L: 3.30

Run no	Roll deg	Drift deg	WA' stbd	WA' port	WA' total
464	20	-15	0.93	0.18	1.11
465	20	-15	0.92	0.18	1.10
463	20	-10	1.04	0.28	1.32
462	20	-5	1.14	0.43	1.58
458	20	0	1.14	0.57	1.71
459	20	5	1.12	0.37	1.49
460	20	10	1.14	0.51	1.64
461	20	15	1.16	0.38	1.54
475	35	-15	1.02	0.19	1.22
474	35	-10	1.04	0.05	1.09
476	35	-10	1.09	0.11	1.21
473	35	-5	1.15	0.06	1.21
468	35	0	1.19	0.12	1.32
469	35	0	1.17	0.12	1.29
470	35	5	1.19	0.37	1.56
471	35	10	1.19	0.32	1.51
472	35	15	1.22	0.26	1.48

TABLE 11   Nondimensional Wetted Area Data
            Speed: 27 knots   R/L: 3.30   Drift Angle: 0 deg
            Rudder Deflection Tests

Run no	Roll deg	Rudder deg	WA' stbd	WA' port	WA' total
322	-20	-30	0.62	1.28	1.91
321	-20	-20	0.62	1.28	1.91
320	-20	0	0.62	1.28	1.91
323	-20	0	0.62	1.28	1.91
319	-20	20	0.62	1.28	1.91
318	-20	30	0.62	1.28	1.91
306	0	-30	1.26	1.22	2.48
305	0	-20	1.26	1.22	2.48
300	0	0	1.26	1.22	2.48
301	0	0	1.26	1.24	2.50
302	0	0	1.27	1.25	2.53
303	0	20	1.27	1.27	2.54
304	0	30	1.27	1.24	2.52
309	20	-30	1.28	0.86	2.15
310	20	-20	1.28	0.74	2.02
311	20	0	1.30	0.86	2.16
312	20	20	1.30	0.99	2.29
313	20	30	1.31	0.97	2.29
314	20	30	1.31	0.99	2.30

TABLE 12   Nondimensional Wetted Area Data
            Speed: 27 knots   R/L: 6.74   Drift Angle: 0 deg
            Rudder Deflection Tests

Run no	Roll deg	Rudder deg	WA' stbd	WA' port	WA' total
287	-20	-30	0.66	0.93	1.59
286	-20	-20	0.63	0.94	1.57
283	-20	0	0.56	0.97	1.53
288	-20	10	0.59	0.95	1.54
284	-20	20	0.61	1.03	1.64
285	-20	30	0.39	1.32	1.71
265	0	-30	0.96	0.95	1.91
262	0	-20	0.95	0.94	1.89
264	0	-20	0.97	0.97	1.95
261	0	0	0.97	0.96	1.94
263	0	0	0.99	0.97	1.96
269	0	10	0.95	0.95	1.90
266	0	20	1.04	1.05	2.09
268	0	30	1.35	1.35	2.70
279	20	-30	1.05	0.46	1.51
278	20	-20	1.12	0.47	1.59
274	20	0	1.09	0.71	1.79
273	20	10	1.09	0.78	1.86
276	20	20	1.14	0.85	1.99
277	20	30	1.27	0.57	1.84

PARTICULARS

Length overall	47.3 ft
Length between perpendiculars	42.9 ft
Max. beam at chine	14.0 ft
Displacement	41,985 lb
LCG, aft of amidships	4.84 ft
VCG, above baseline	5.04 ft
Propeller diameter	2.33 ft
Model scale ratio	9.032

PROFILE

HALF BREADTH PLAN

BODY PLAN
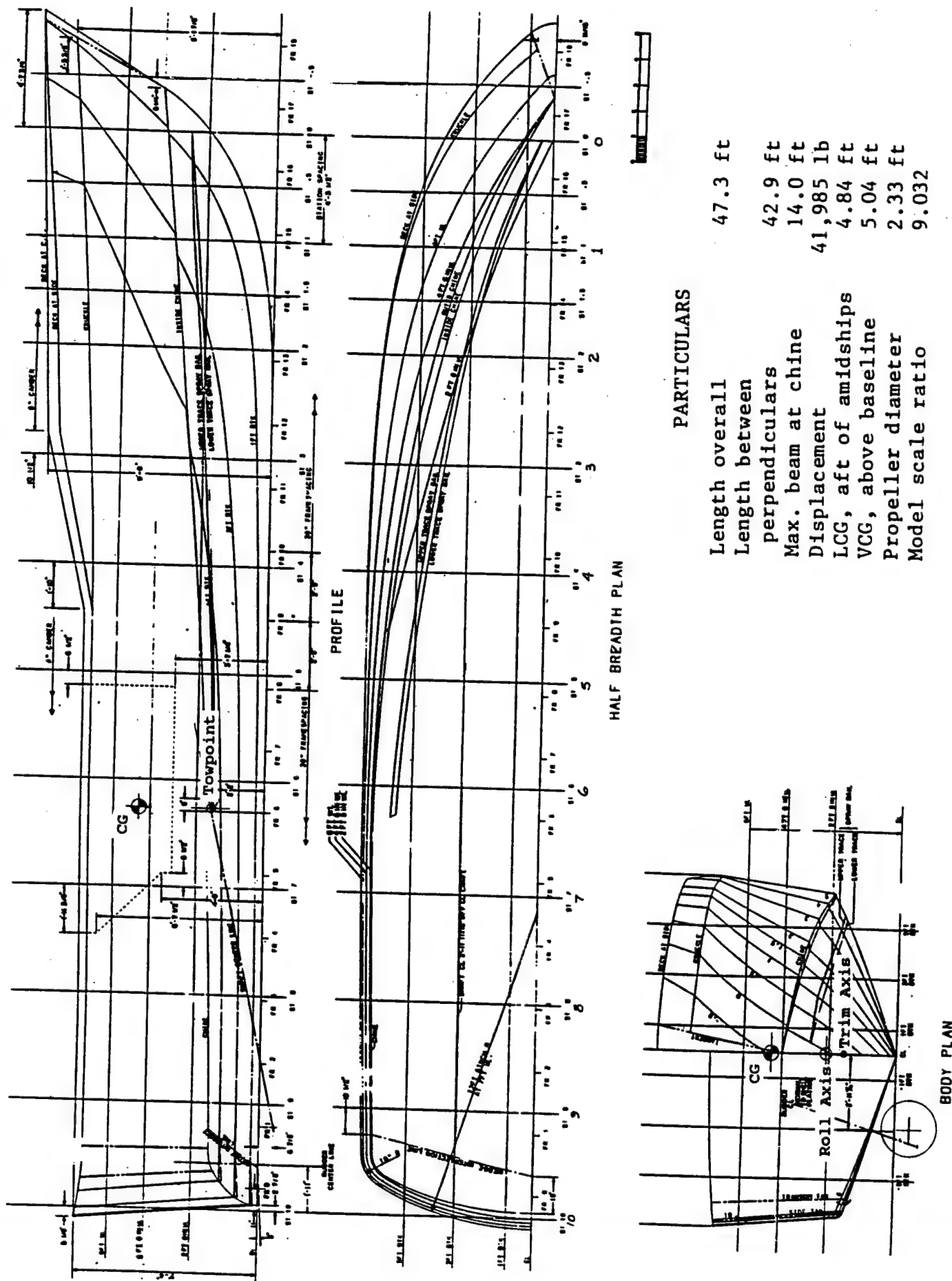
Figure 1. Lines and Particulars of the 47-FT Motor Lifeboat

28

Figure 2. Rudder details. Dimensions in full-scale inches.
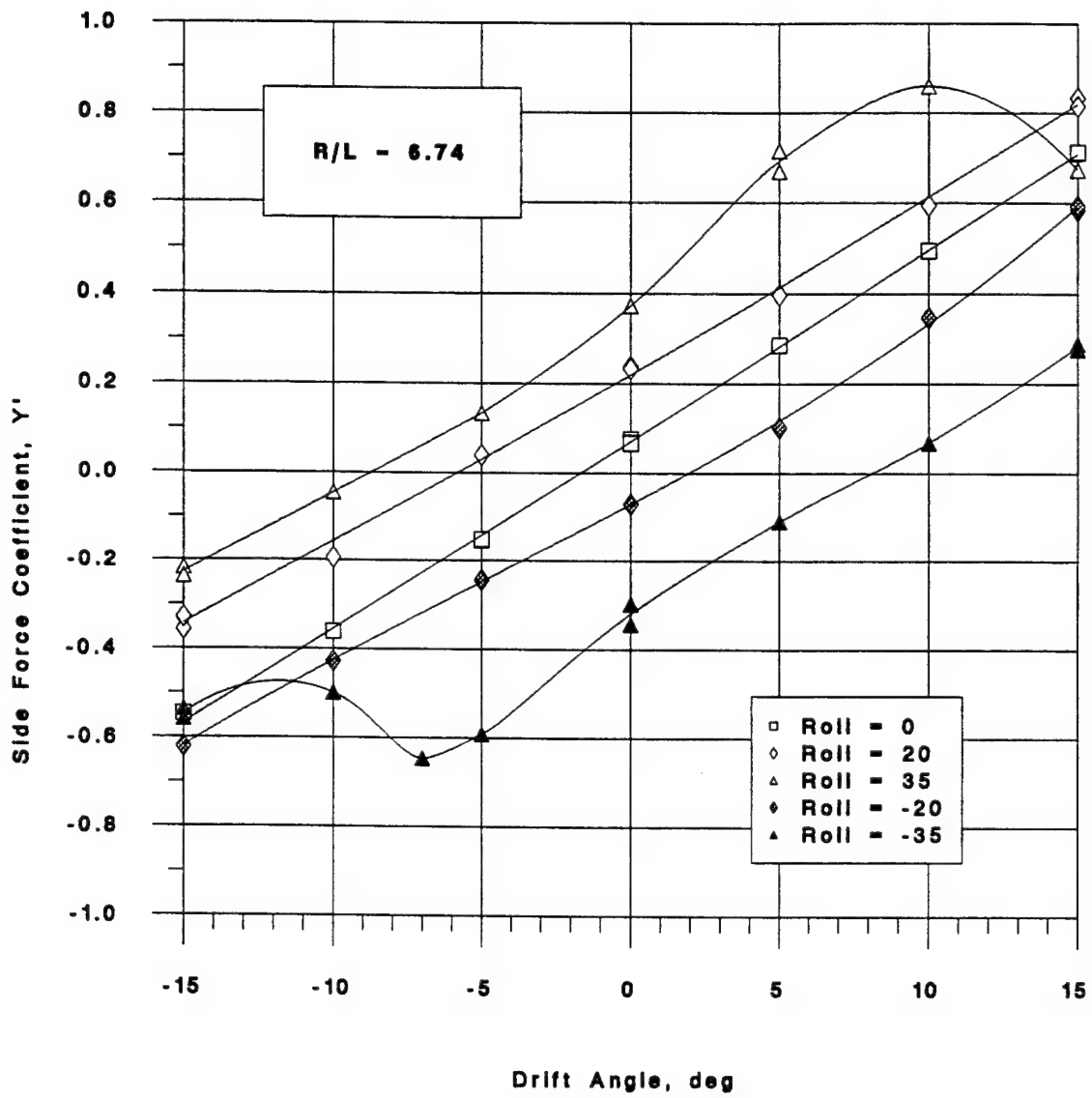
Figure 3.   Behavior of Side Force with Drift and
Roll Angles at 27 knots
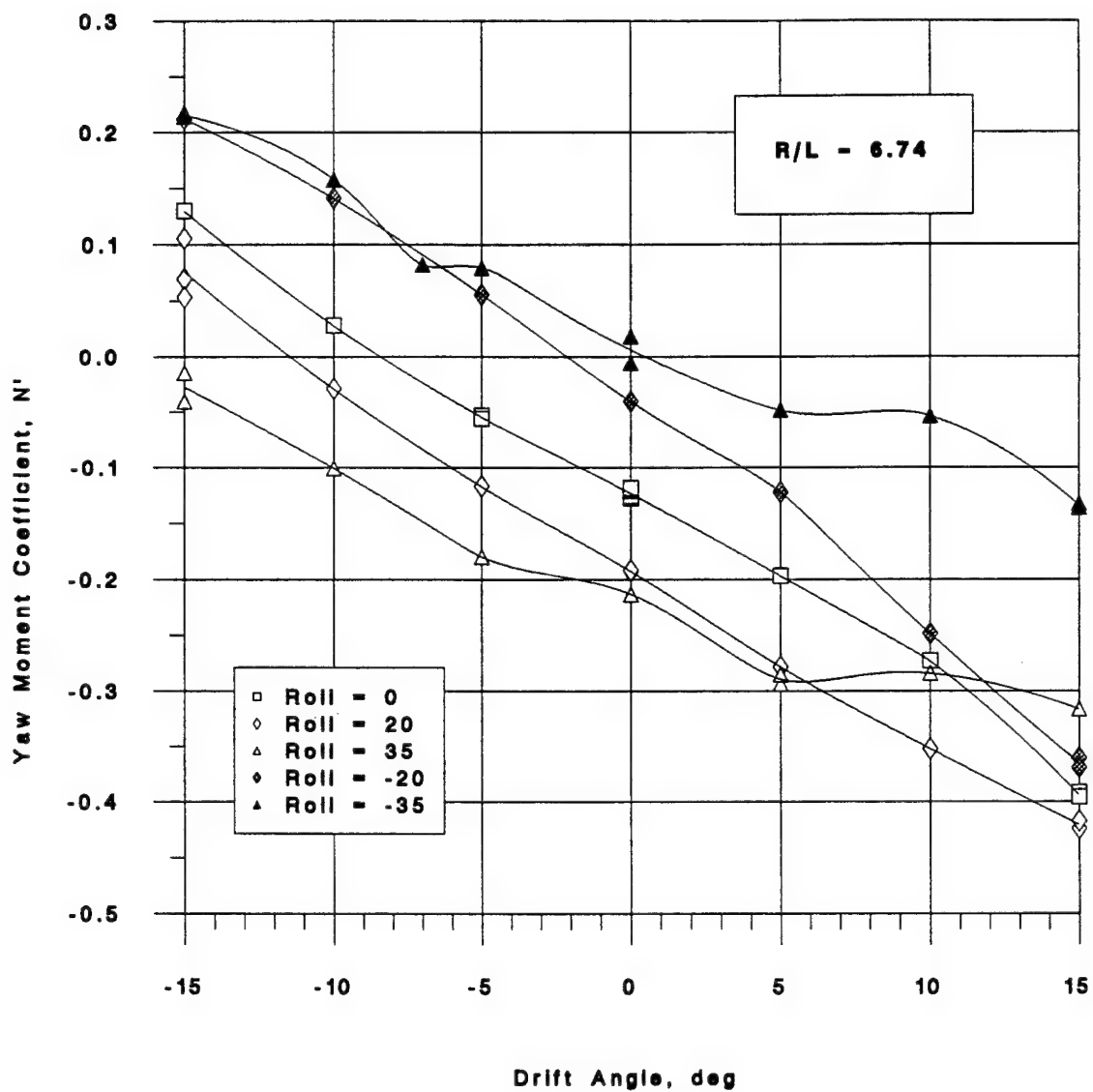
Figure 4.   Behavior of Yaw Moment with Drift and
Roll Angles at 27 Knots
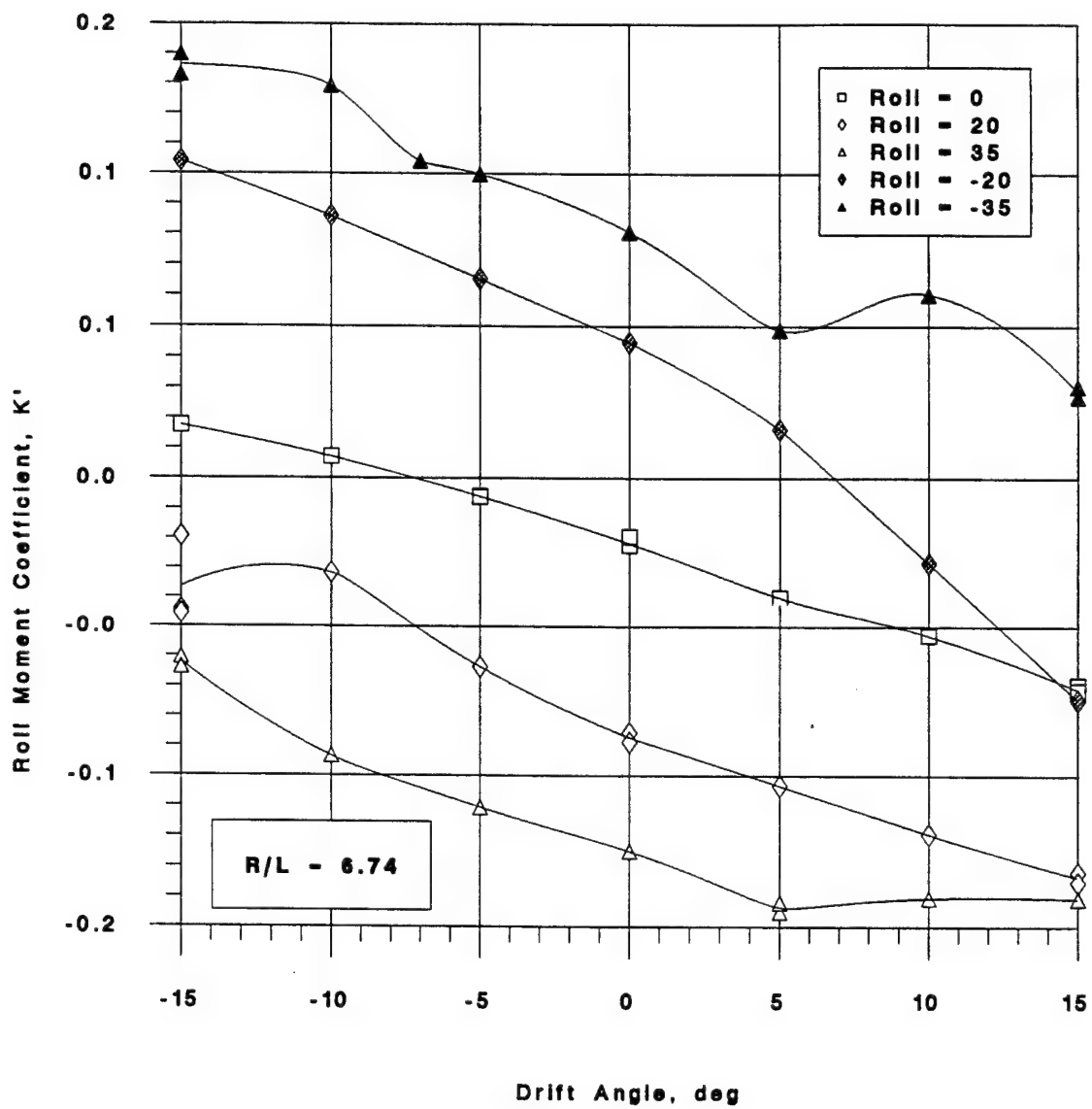
Figure 5. Behavior of Roll Moment with Drift and Roll Angles at 27 Knots
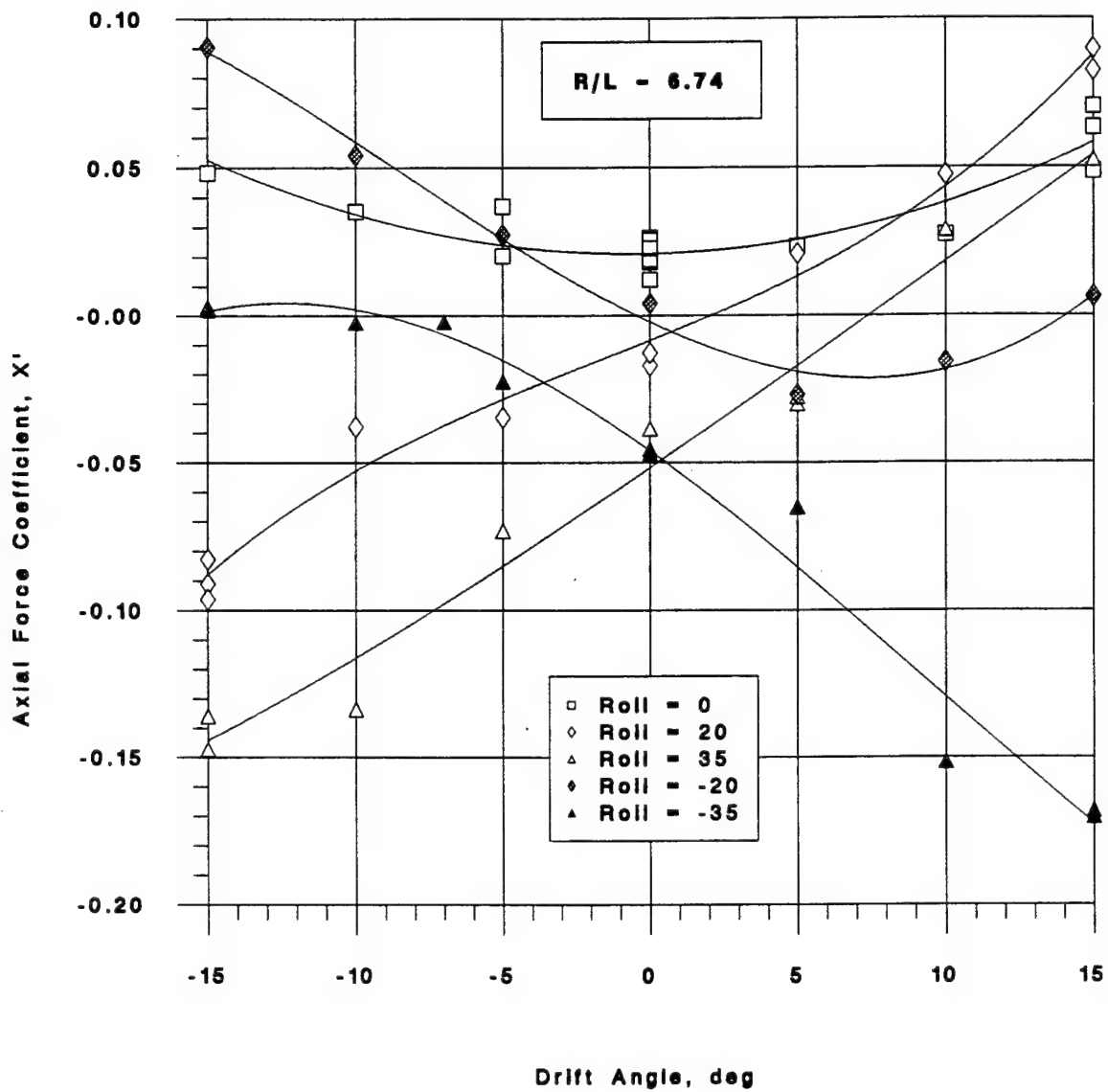
Figure 6.   Behavior of Axial Force with Drift and Roll Angles at 27 Knots
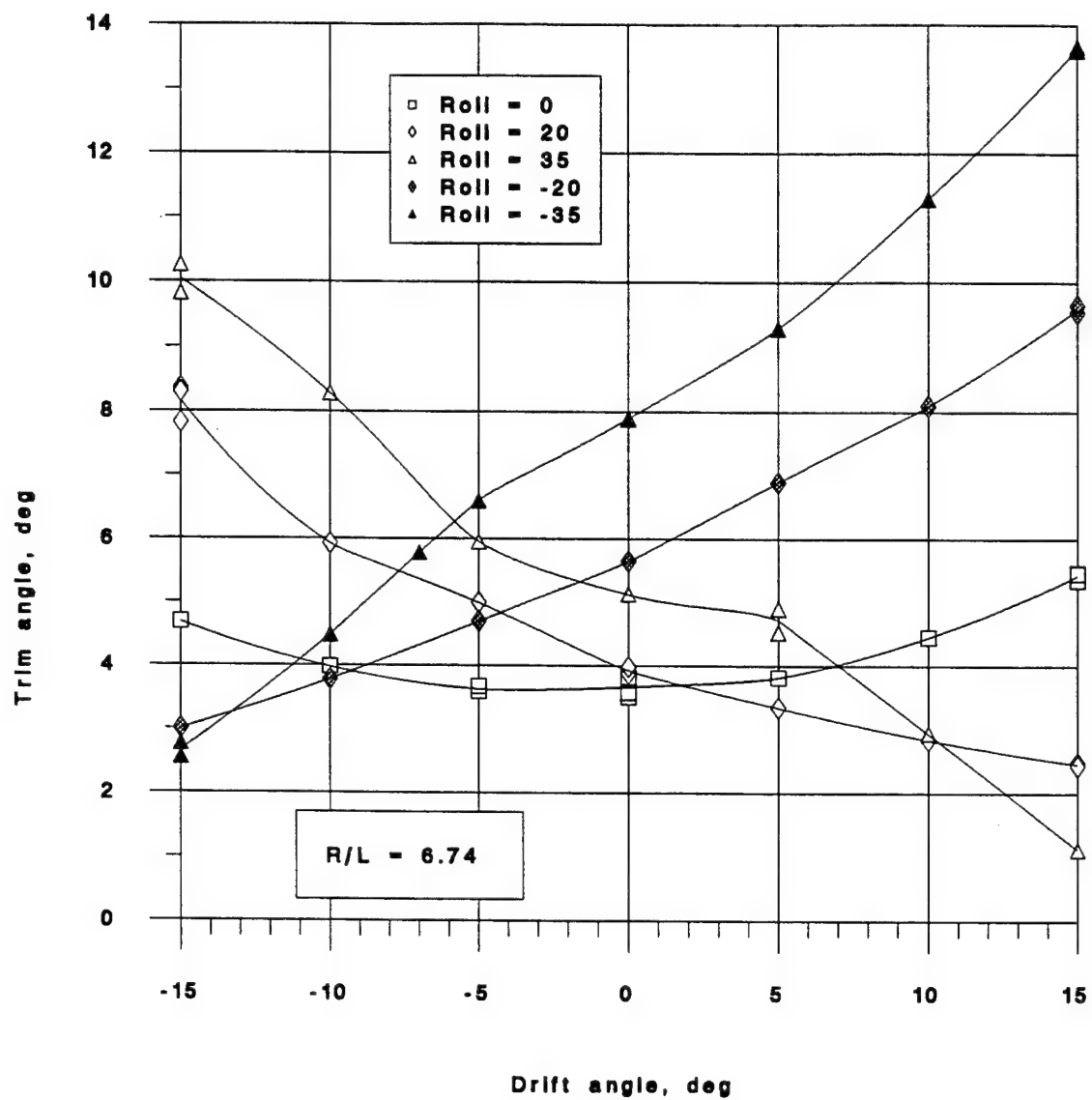
Figure 7.   Behavior of Trim Angle with Drift and
Roll Angles at 27 Knots

34
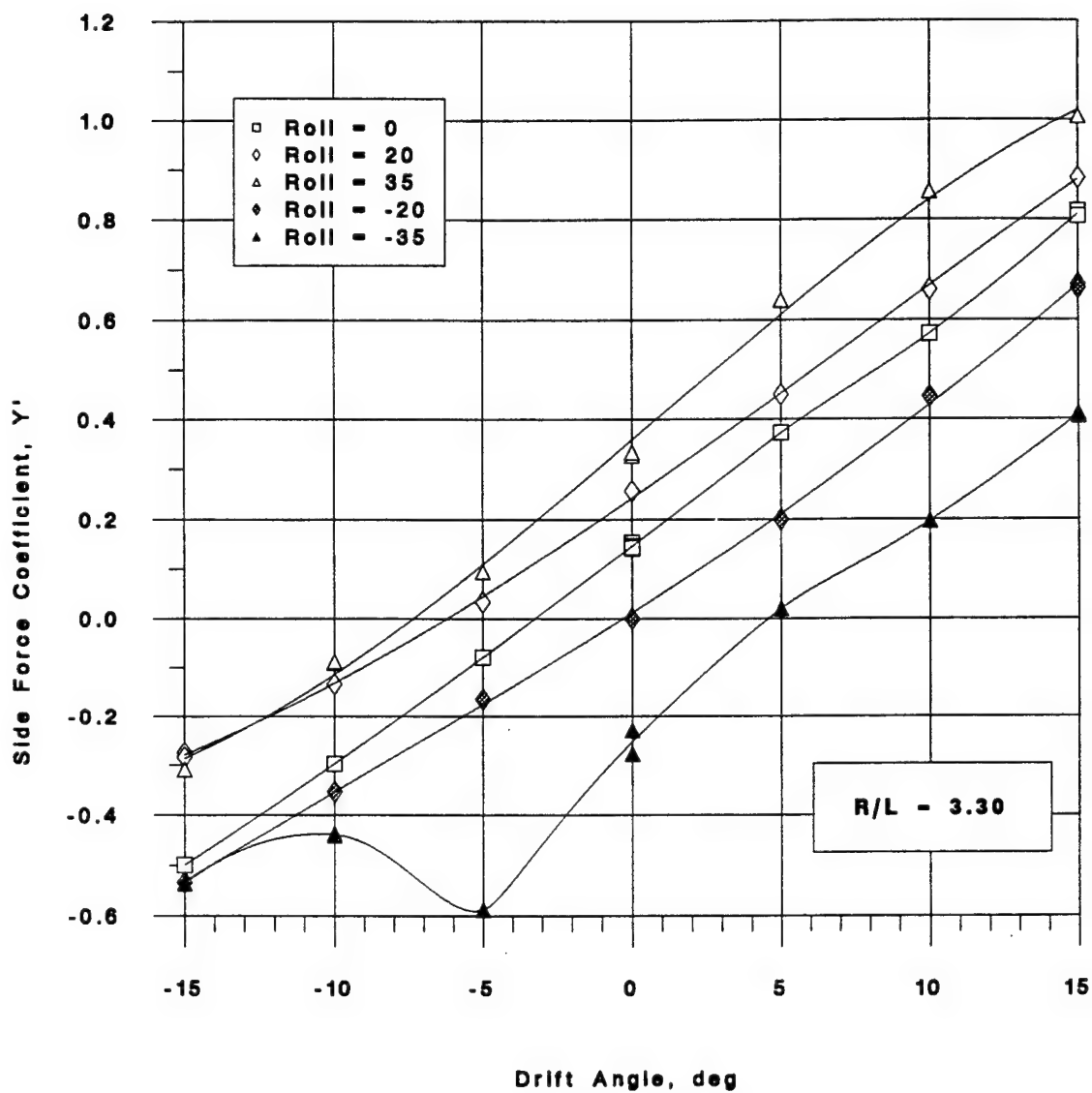
Figure 8.   Behavior of Side Force with Drift and
             Roll Angles at 27 knots

35
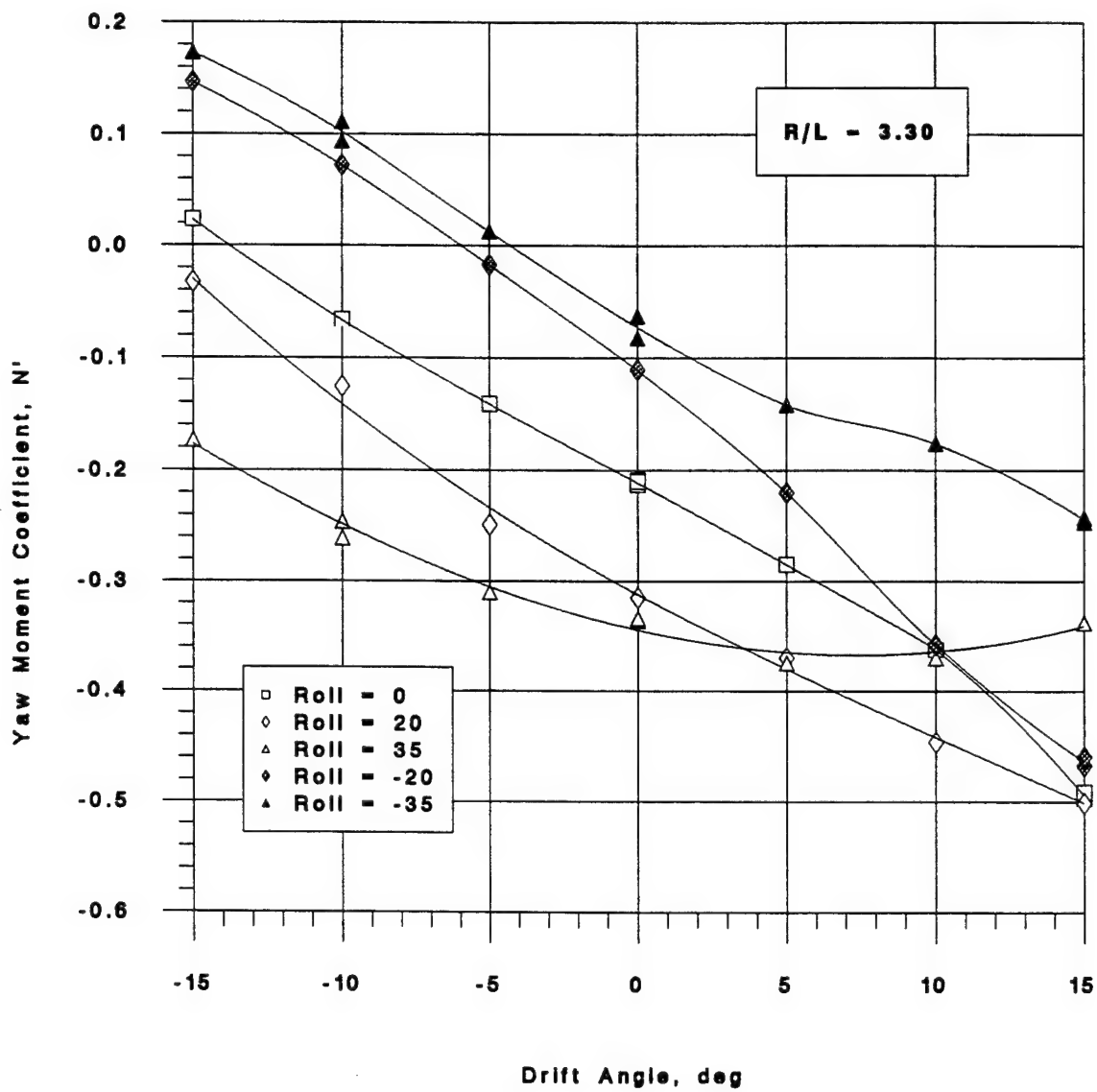
Figure 9.   Behavior of Yaw Moment with Drift and
Roll Angles at 27 Knots
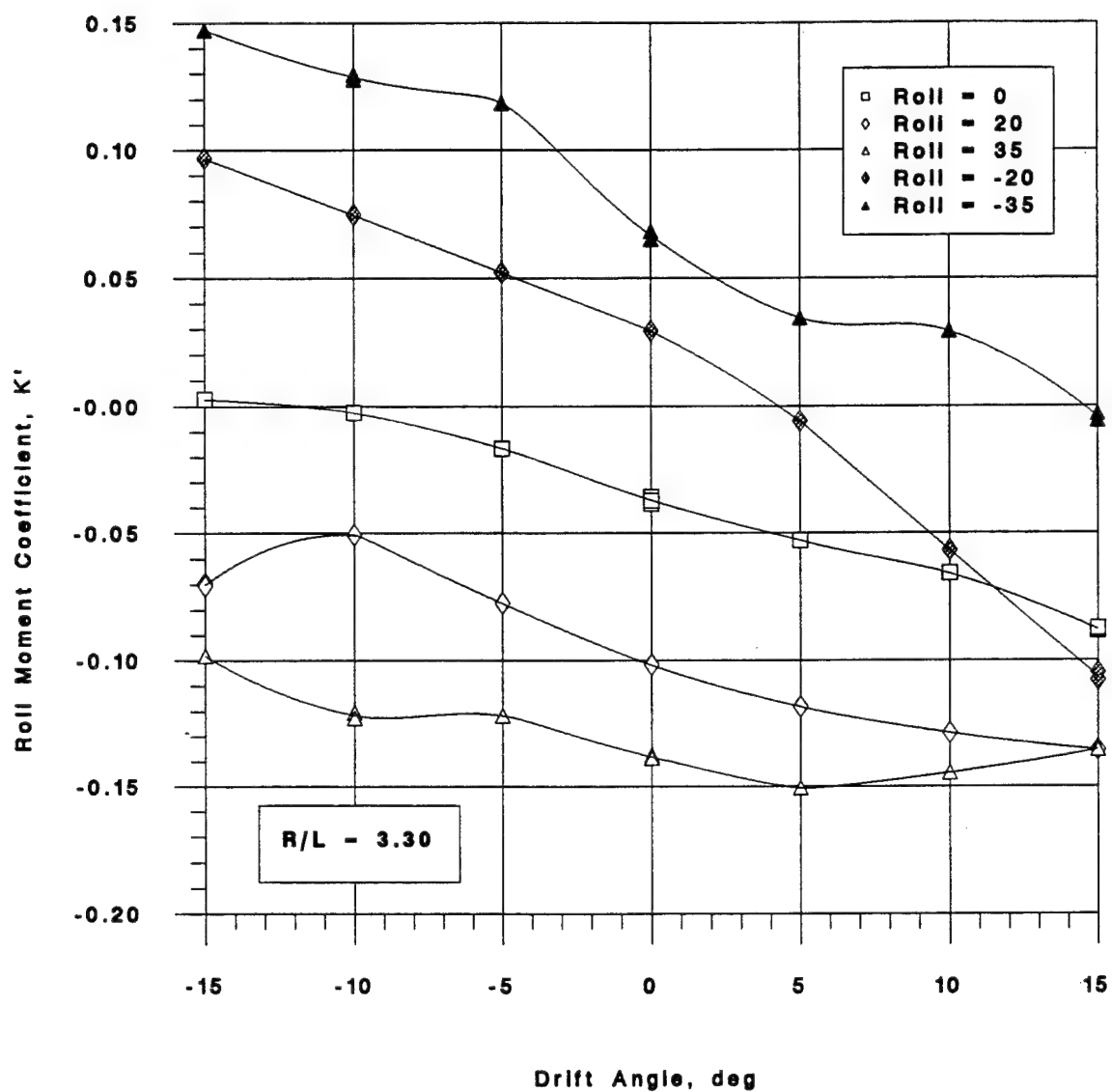
Figure 10.   Behavior of Roll Moment with Drift and
                Roll Angles at 27 knots
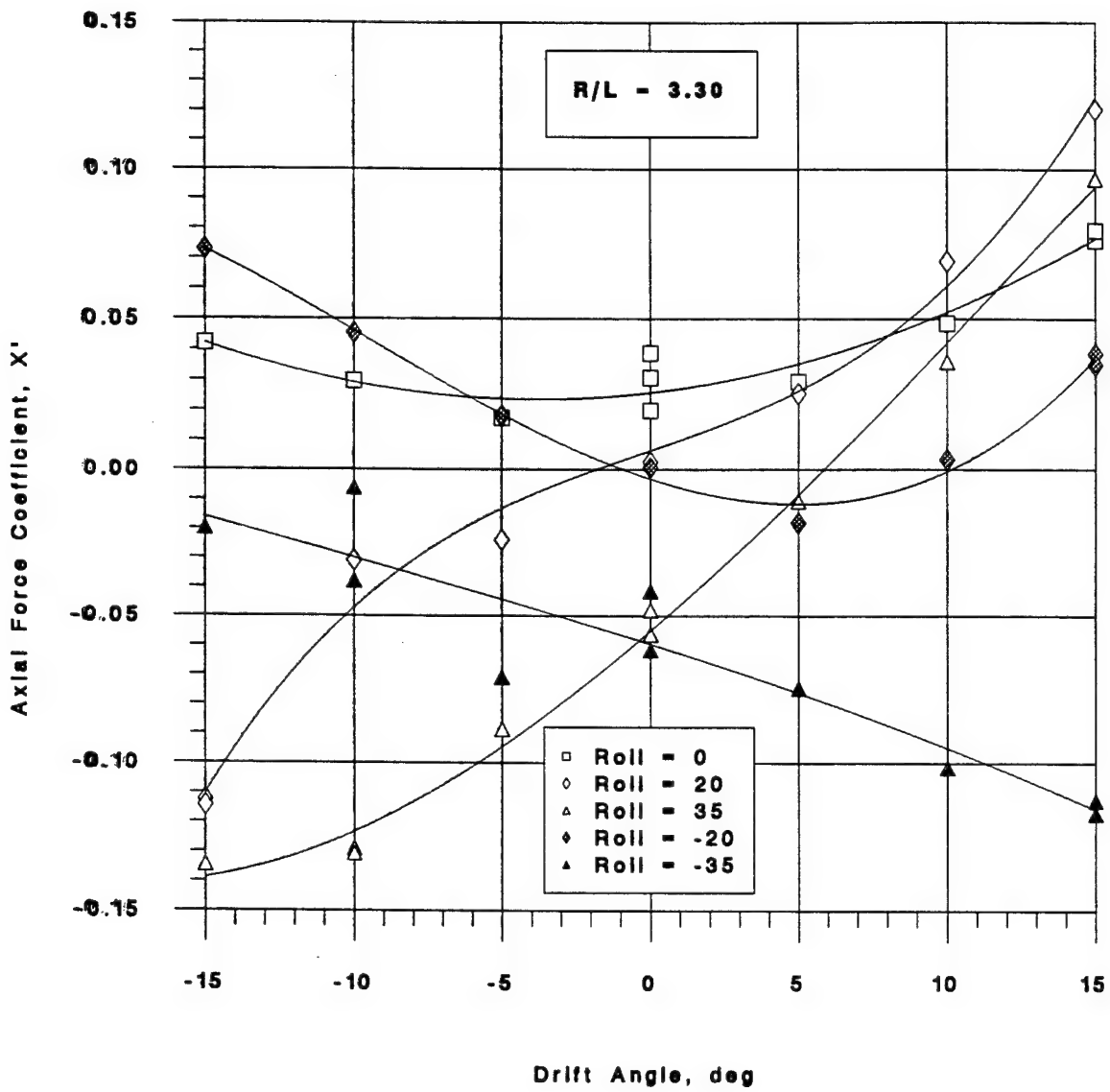
Figure 11.   Behavior of Axial Force with Drift and
Roll Angles at 27 Knots

38
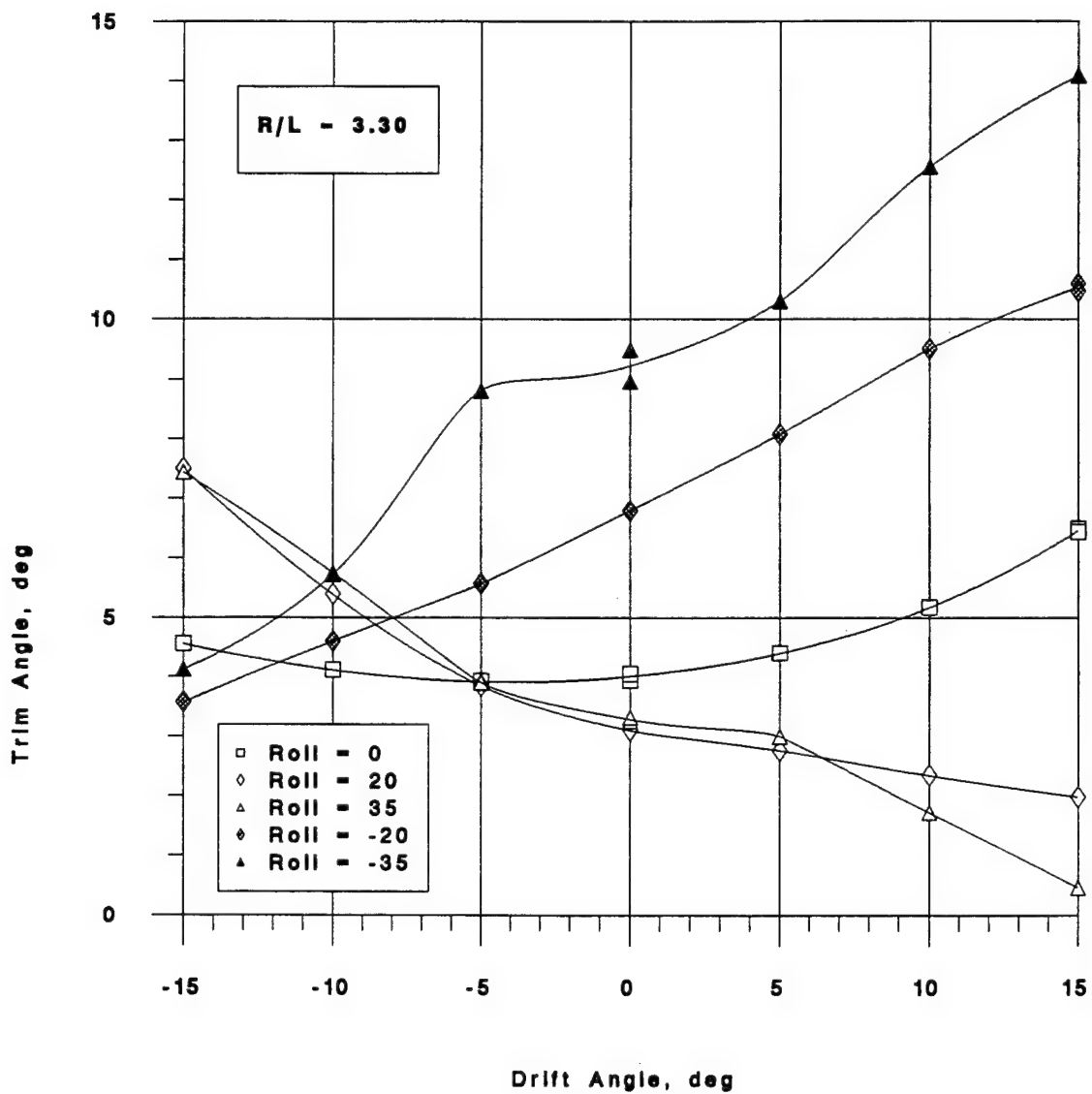
Figure 12. Behavior of Trim Angle with Drift and Roll Angles at 27 Knots
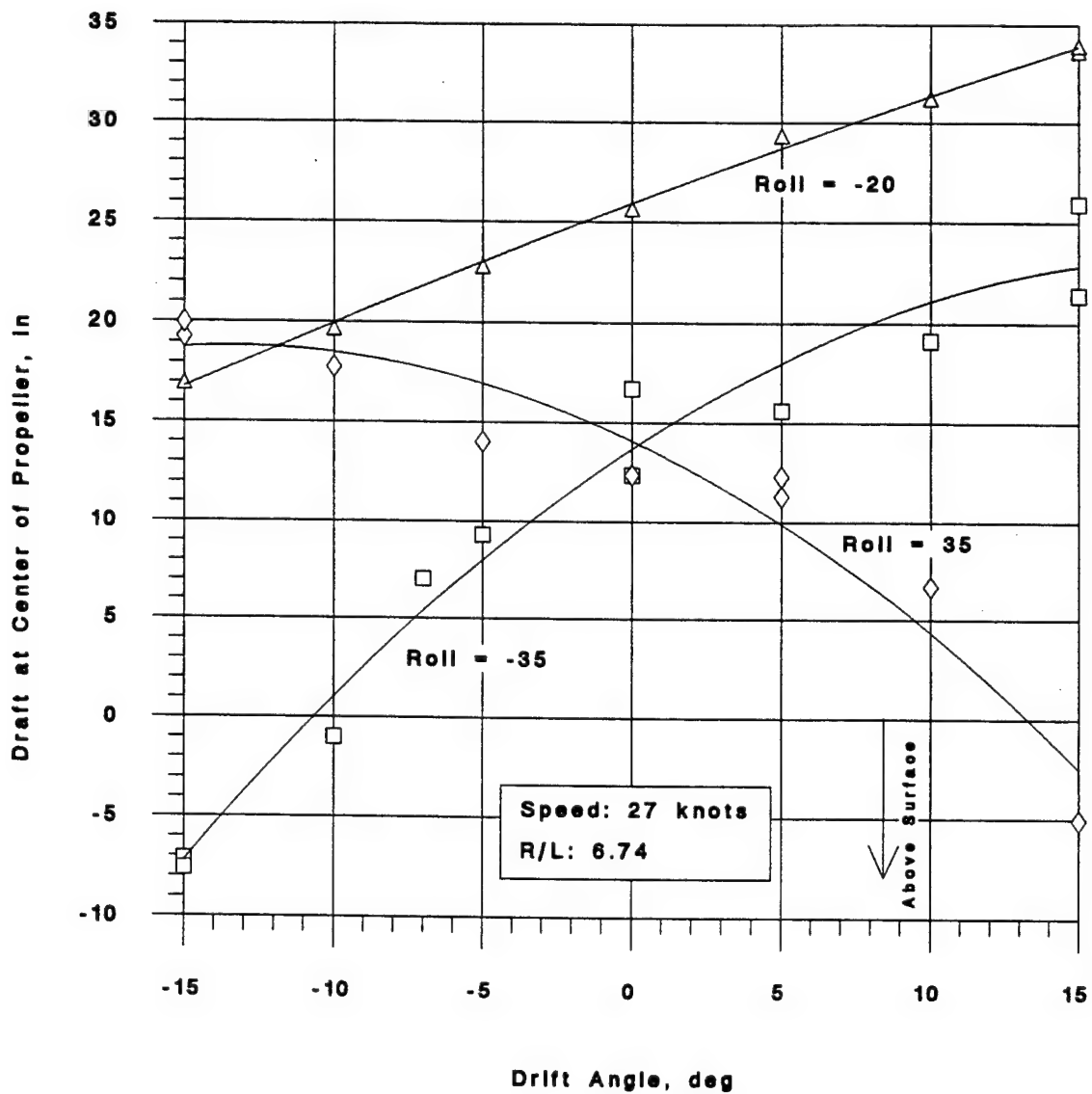
Figure 13. Distance below Calm Water Surface to Center of Highest Propeller at Several Roll Angles
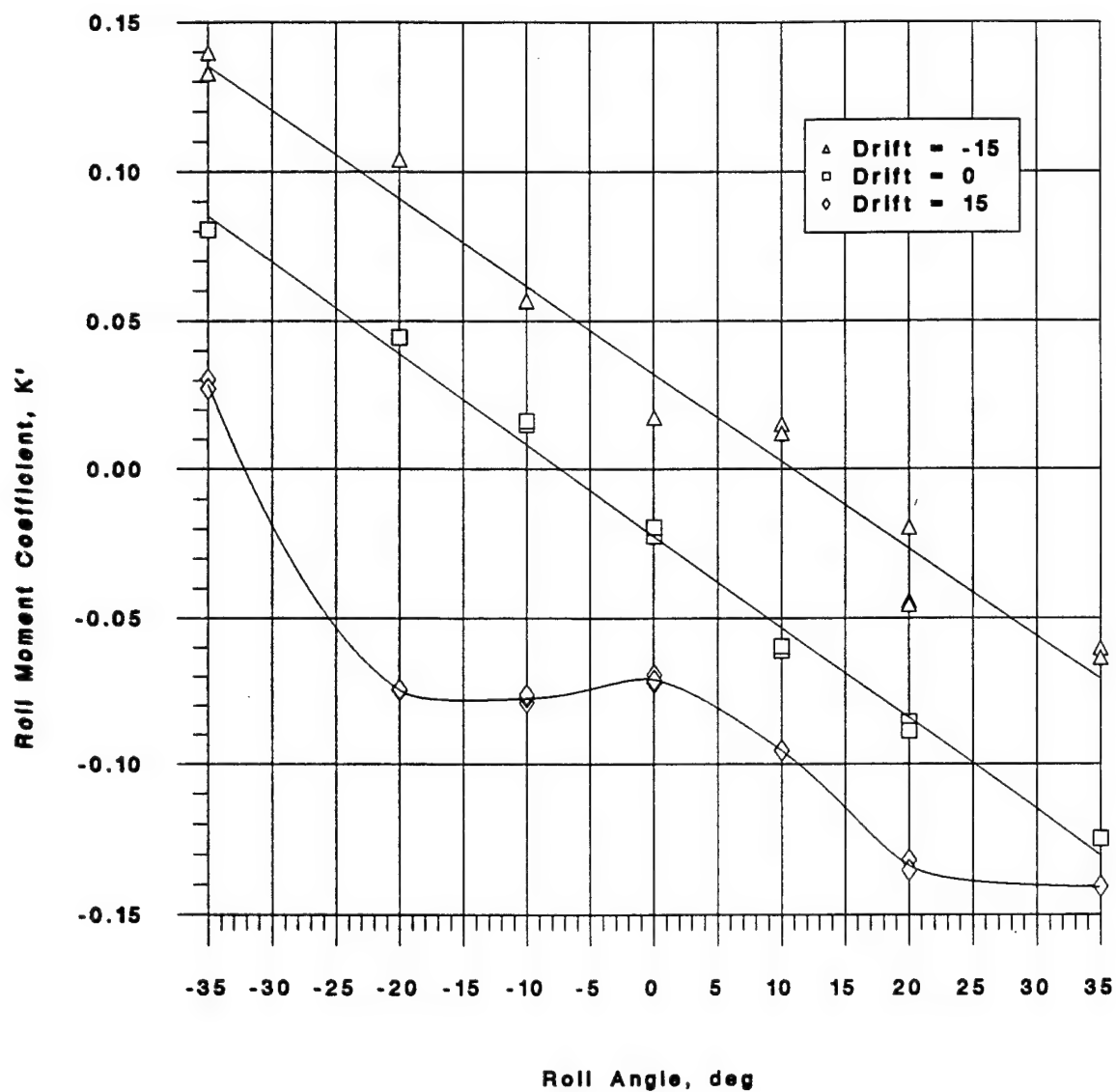
Figure 14. Behavior of Roll Moment with Roll Angle
Speed: 27 knots   R/L: 6.74

41
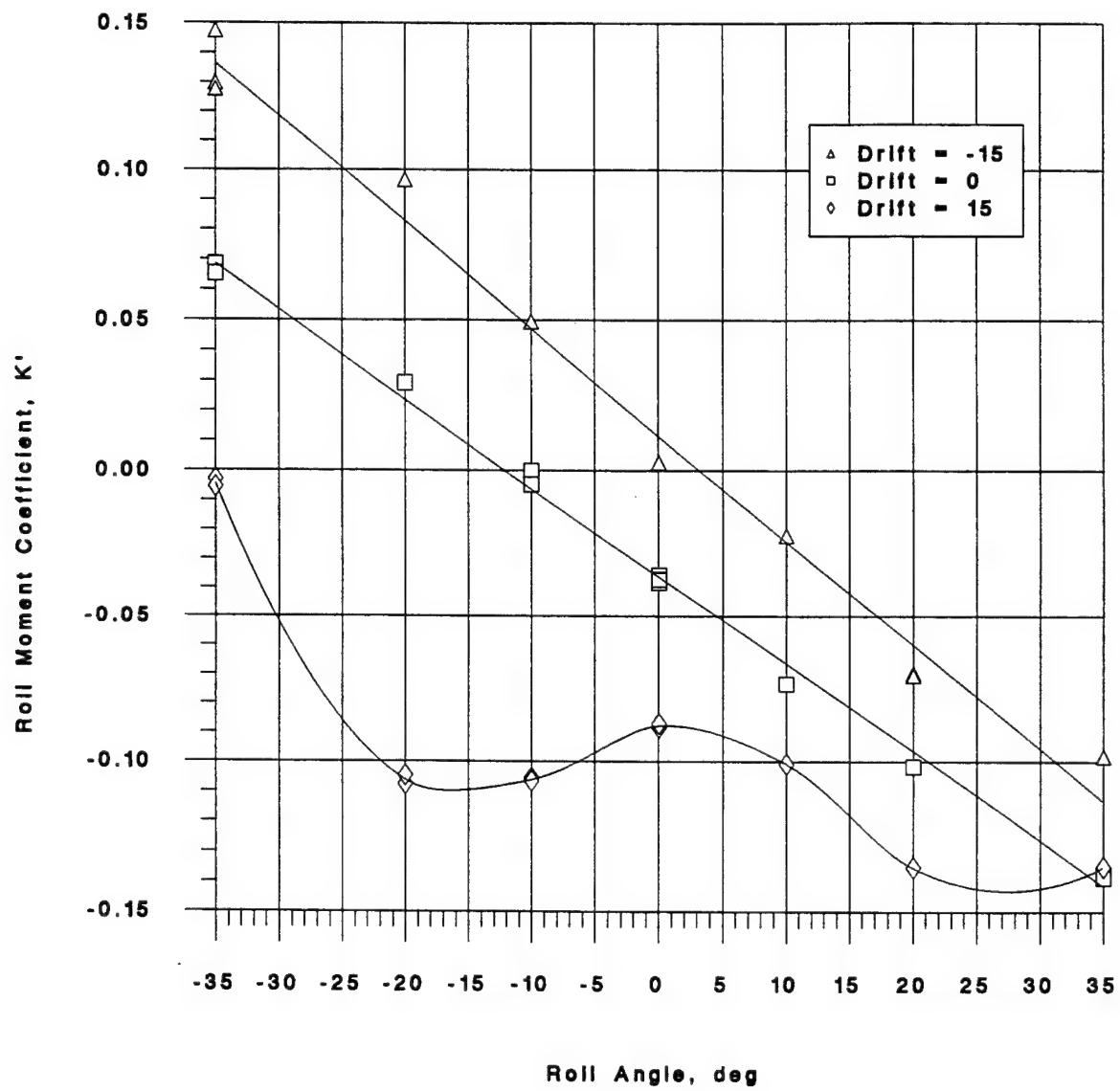
Figure 15.   Behavior of Roll Moment with Roll Angle
             Speed: 27 knots   R/L: 3.30
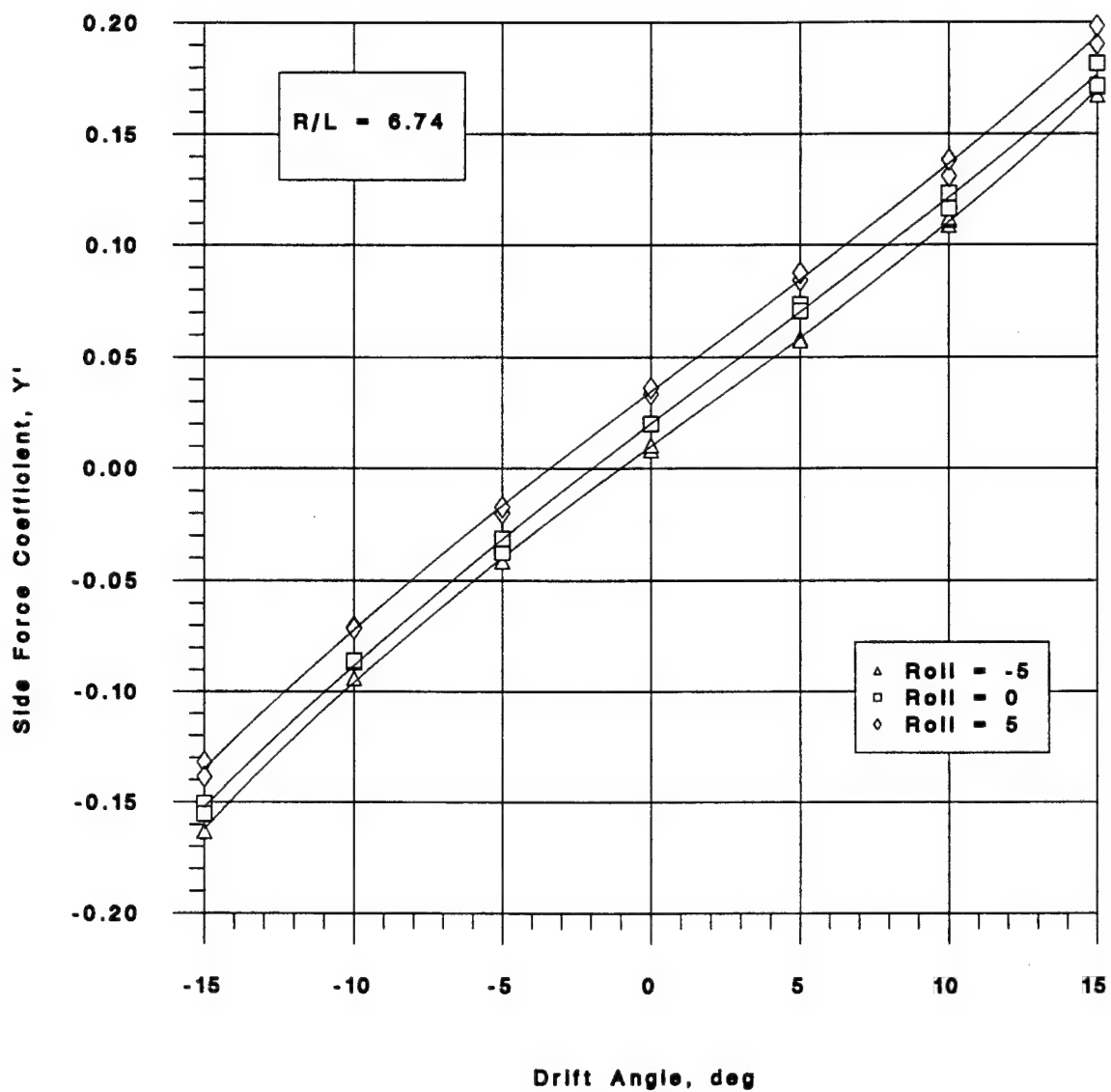
Figure 16. Behavior of Side Force with Drift and Roll Angles at 10 Knots
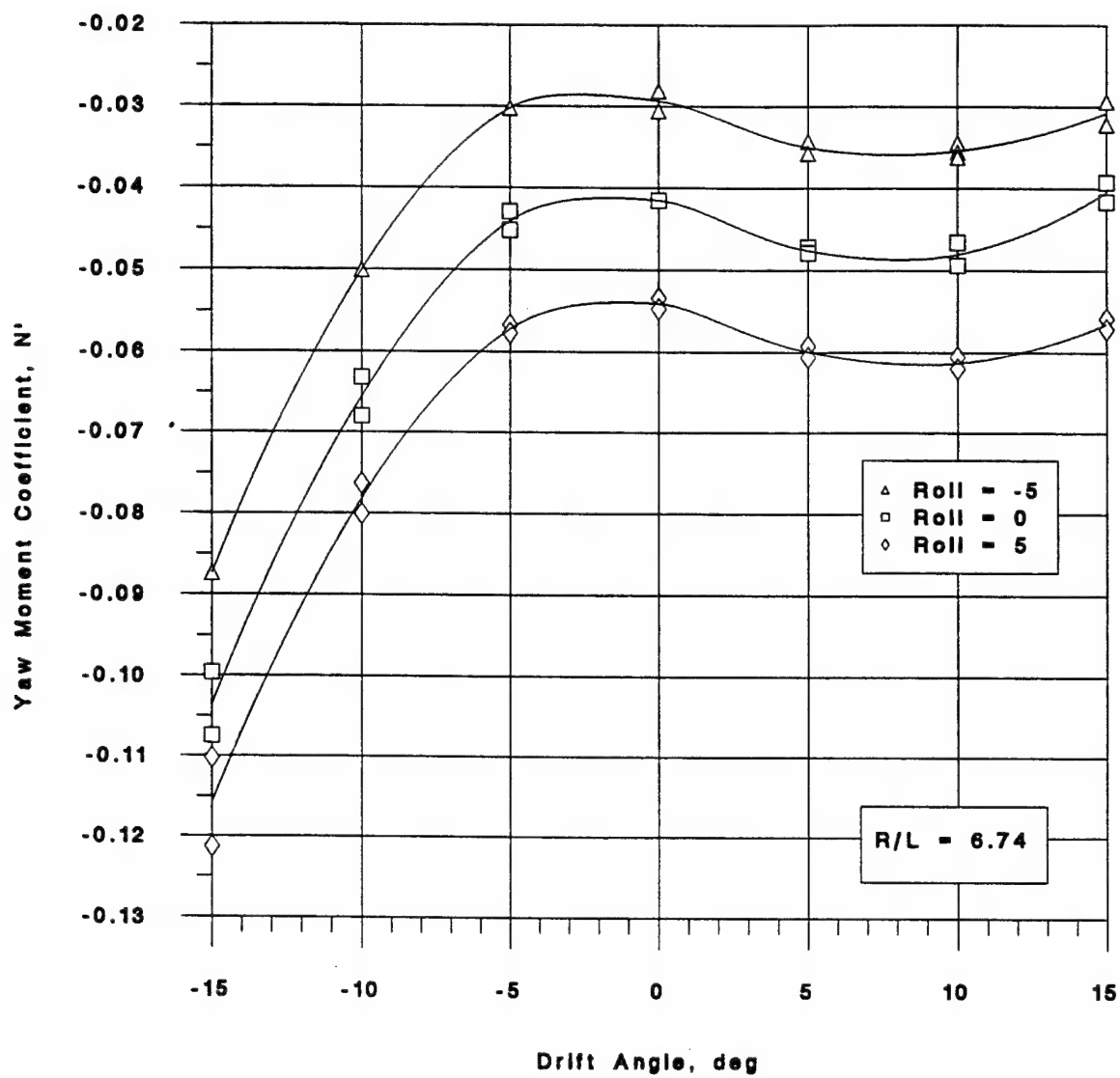
Figure 17. Behavior of Yaw Moment with Drift and
Roll Angles at 10 Knots

44
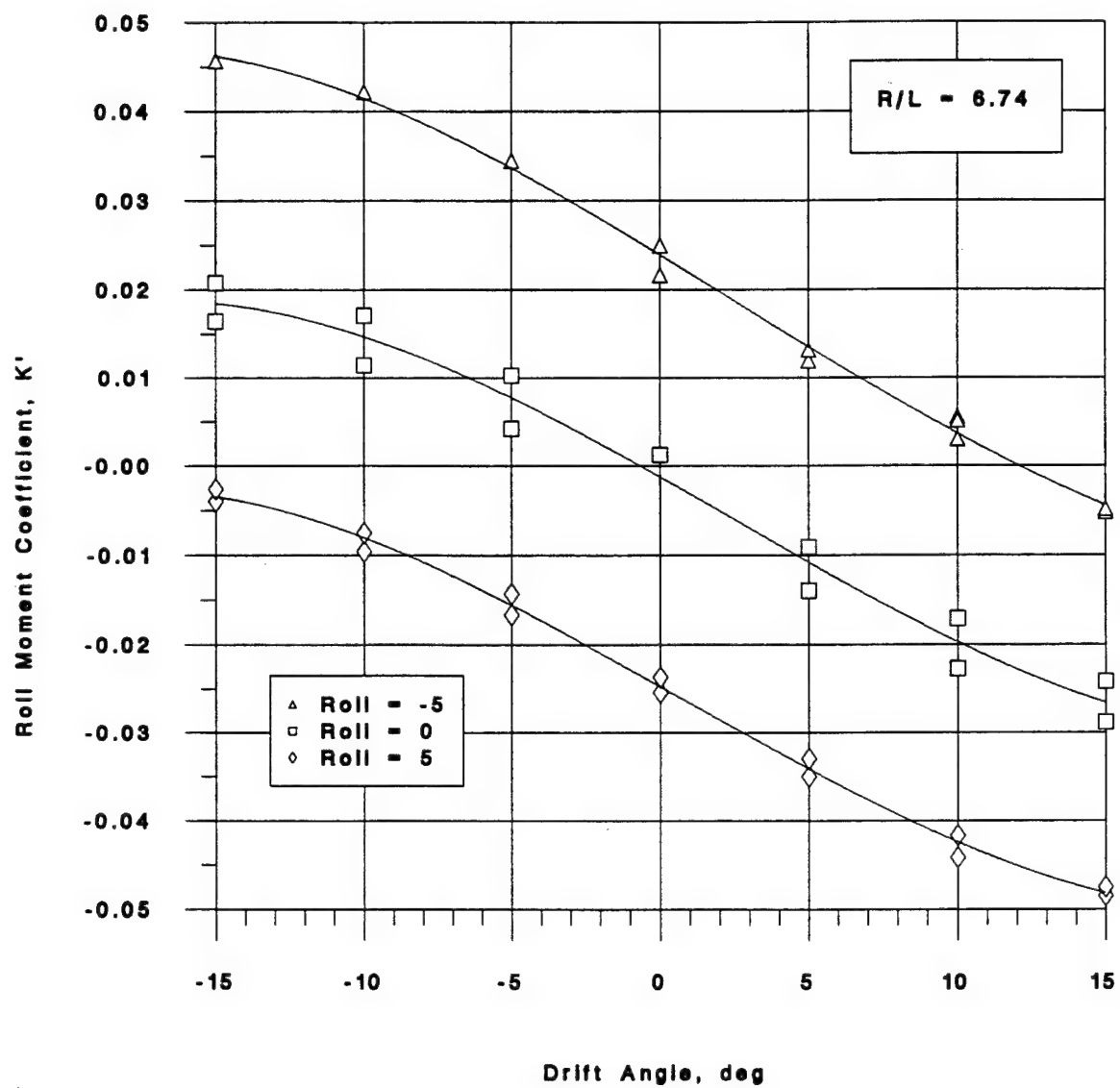
Figure 18. Behavior of Roll Moment with Drift
and Roll Angles at 10 Knots
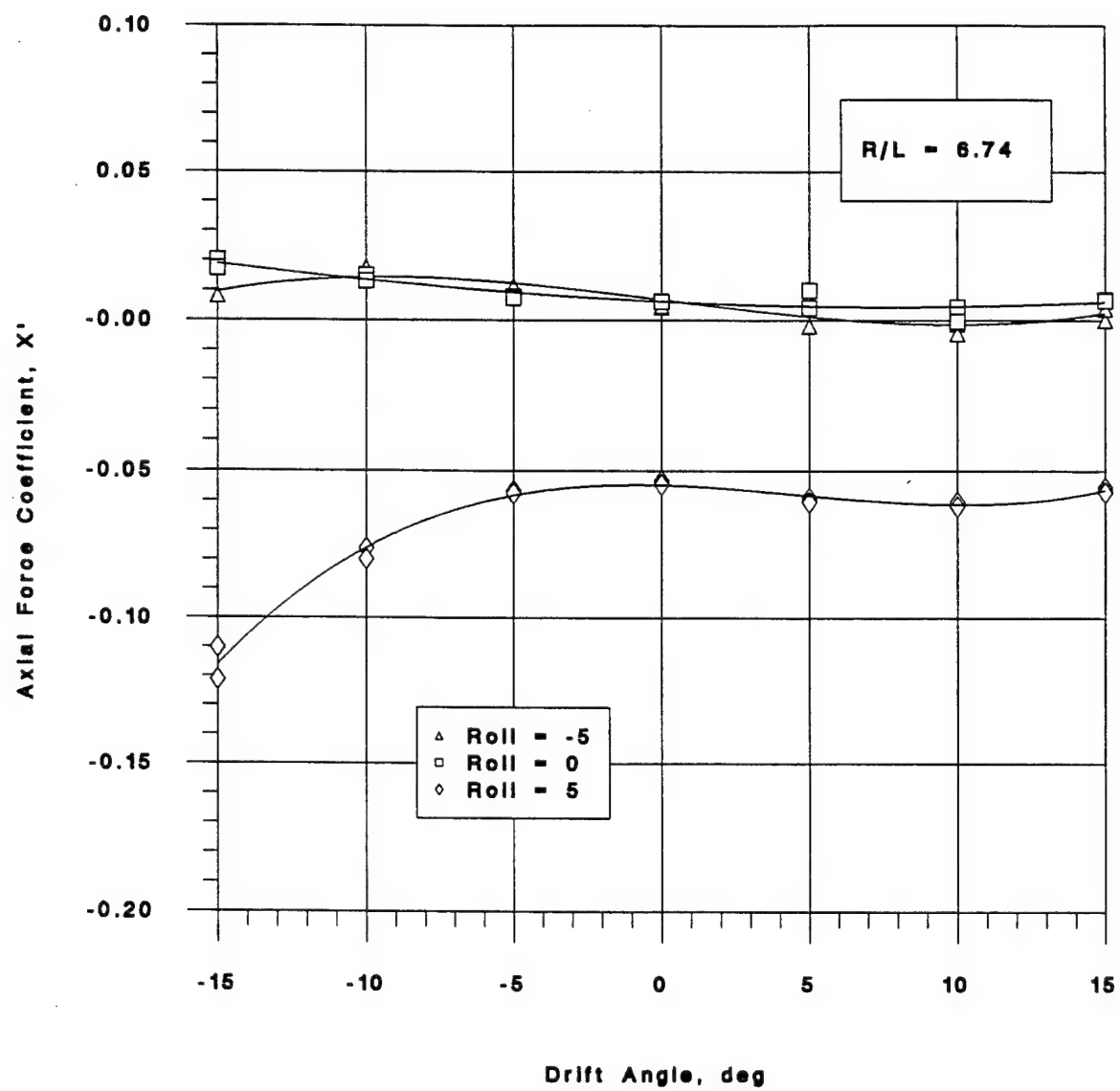
Figure 19.   Behavior of Axial Force with Drift and Roll Angles at 10 Knots

46
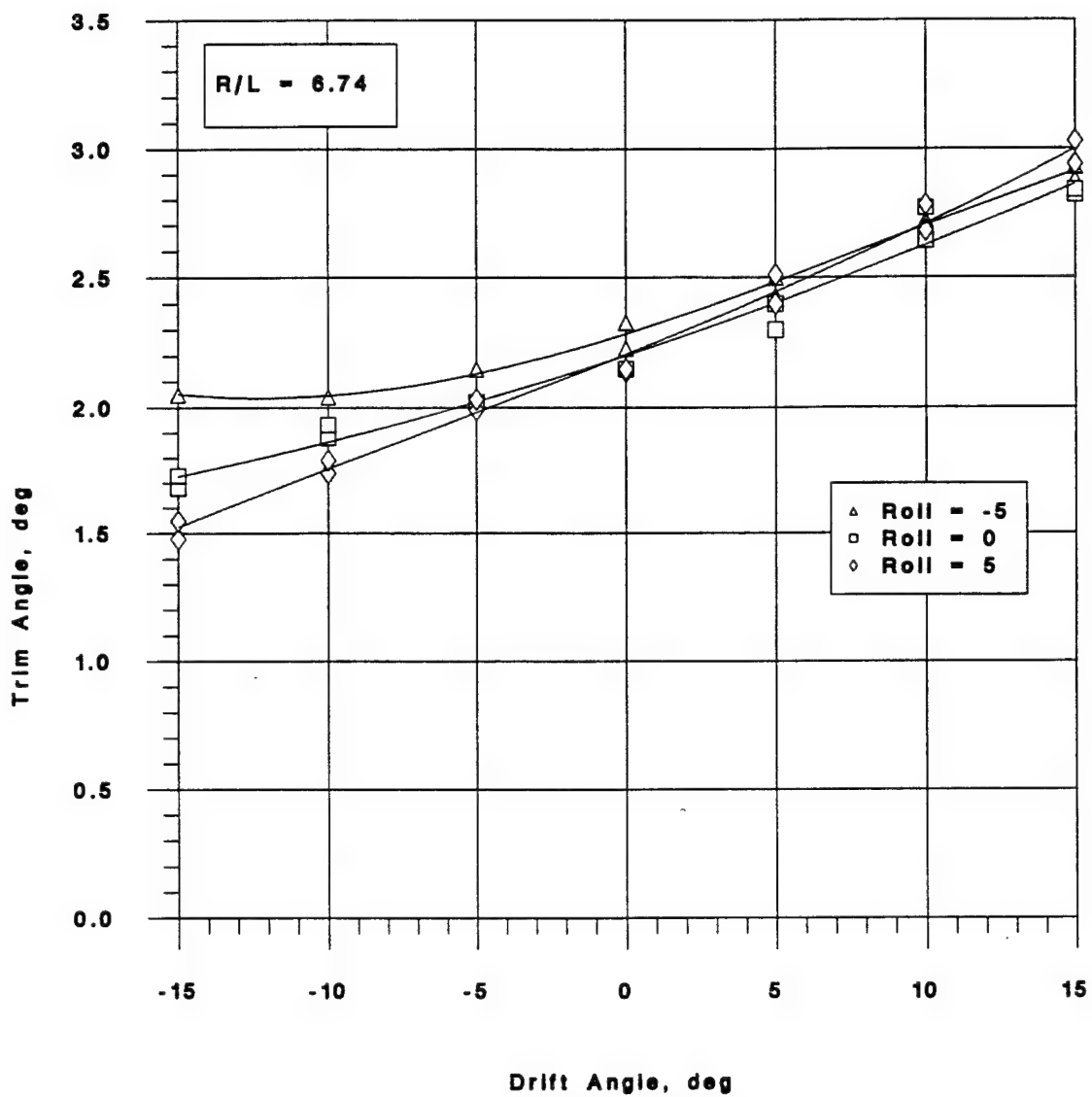
Figure 20.   Behavior of Trim Angle with Drift and
Roll Angles at 10 Knots

47
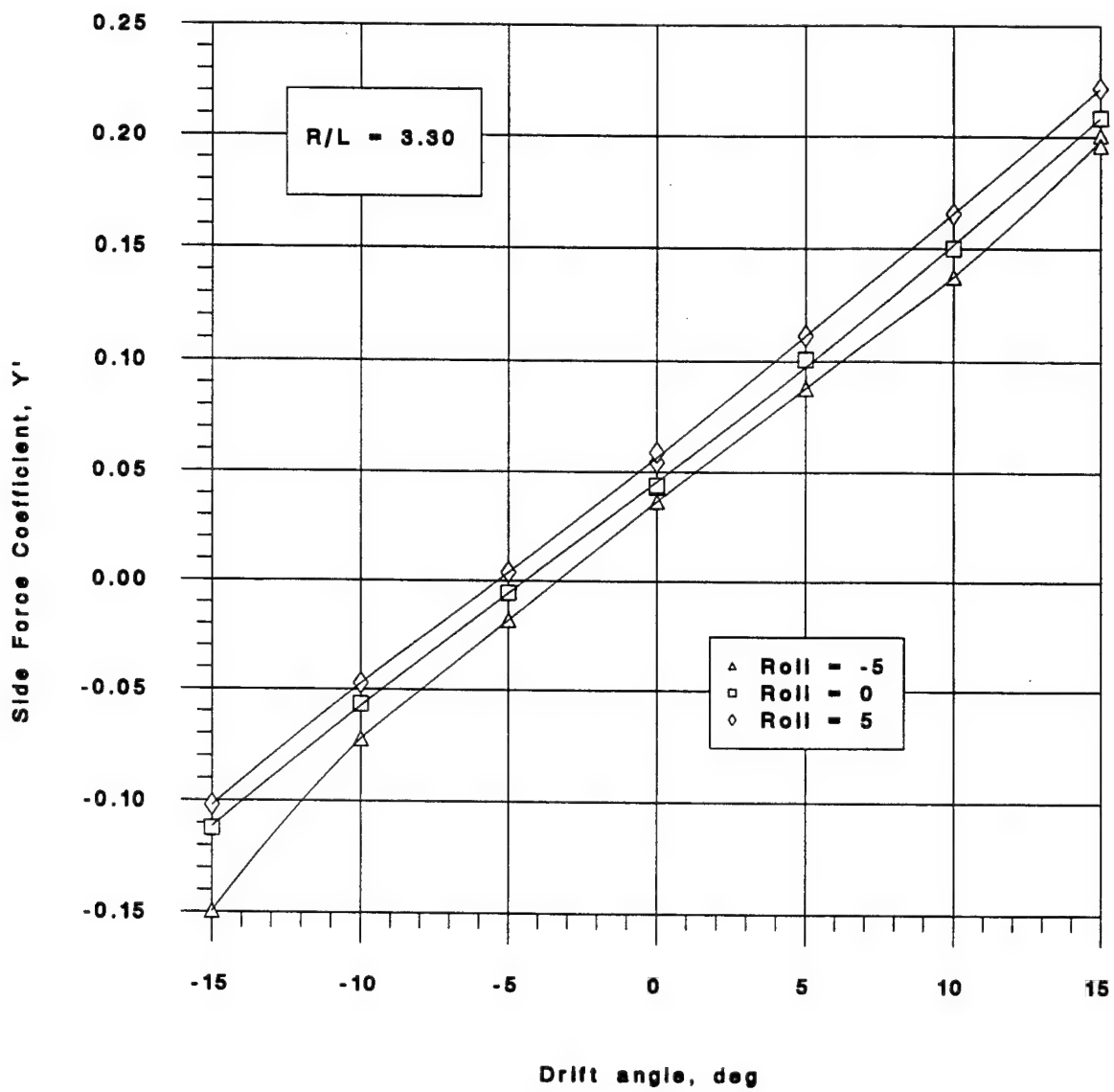
Figure 21.   Behavior of Side Force with Drift and Roll Angles
at 10 knots
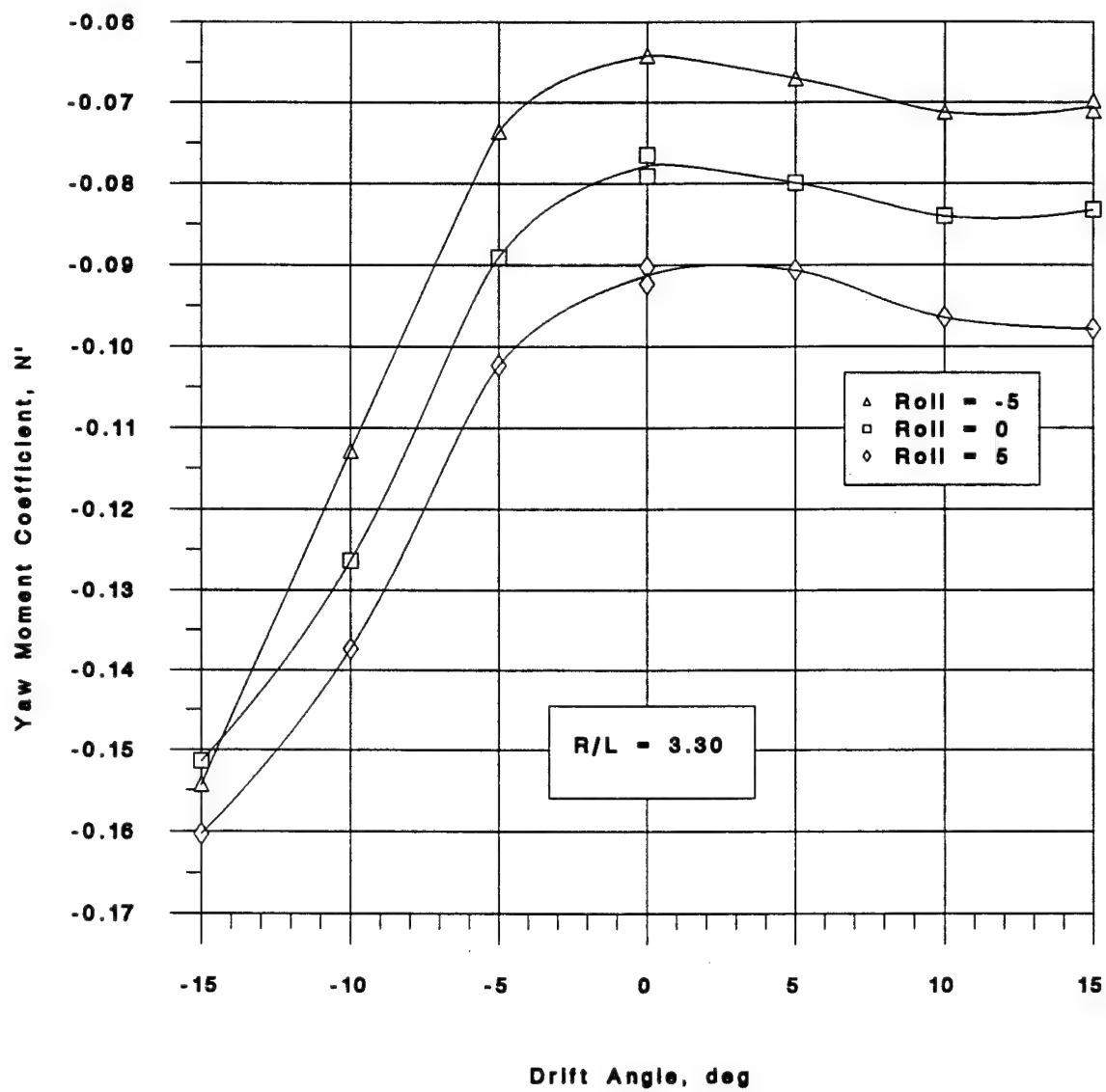
Figure 22.   Behavior of Yaw Moment with Drift and
Roll Angles at 10 Knots
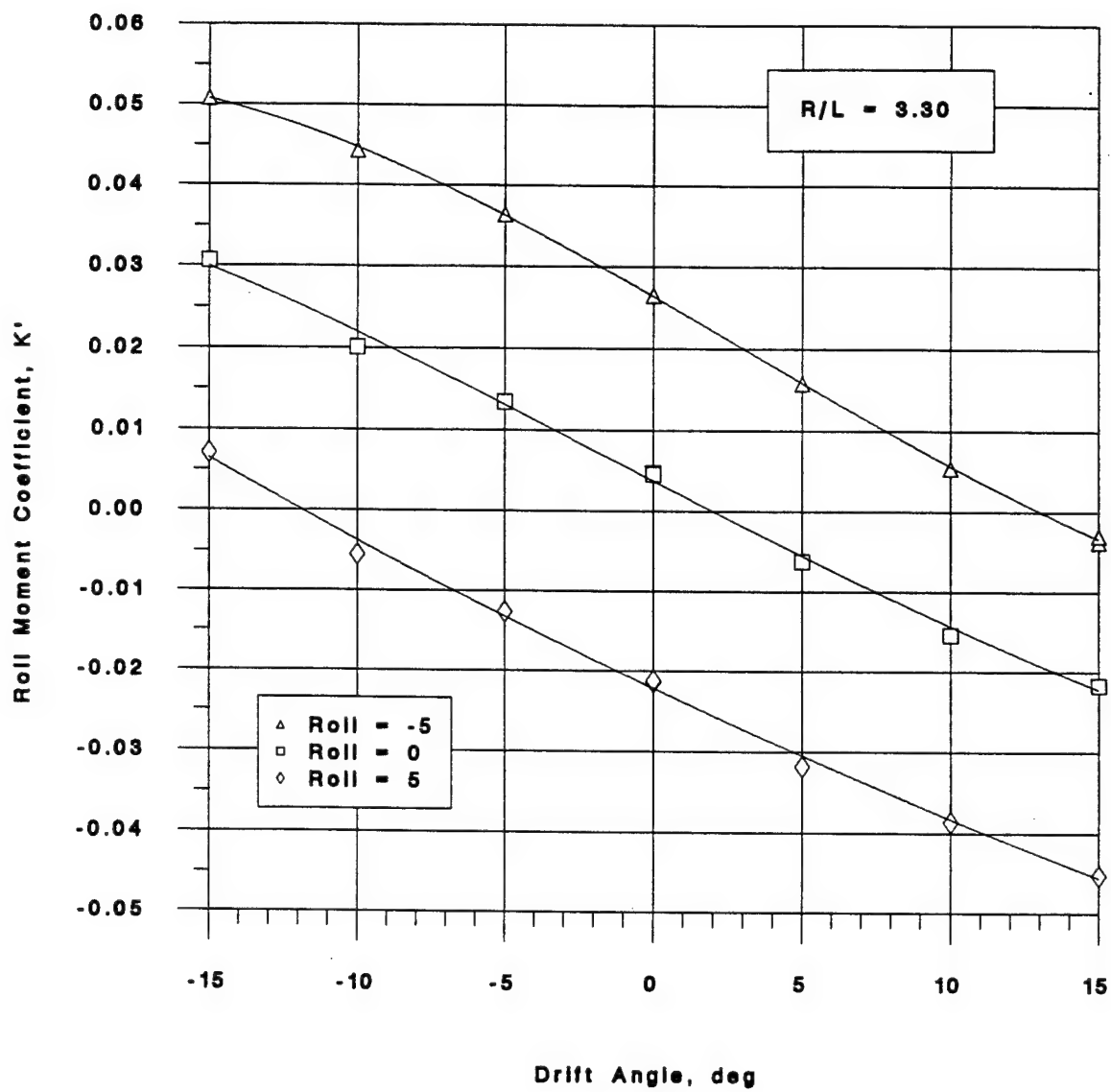
Figure 23. Behavior of Roll Moment with Drift and Roll Angles at 10 knots
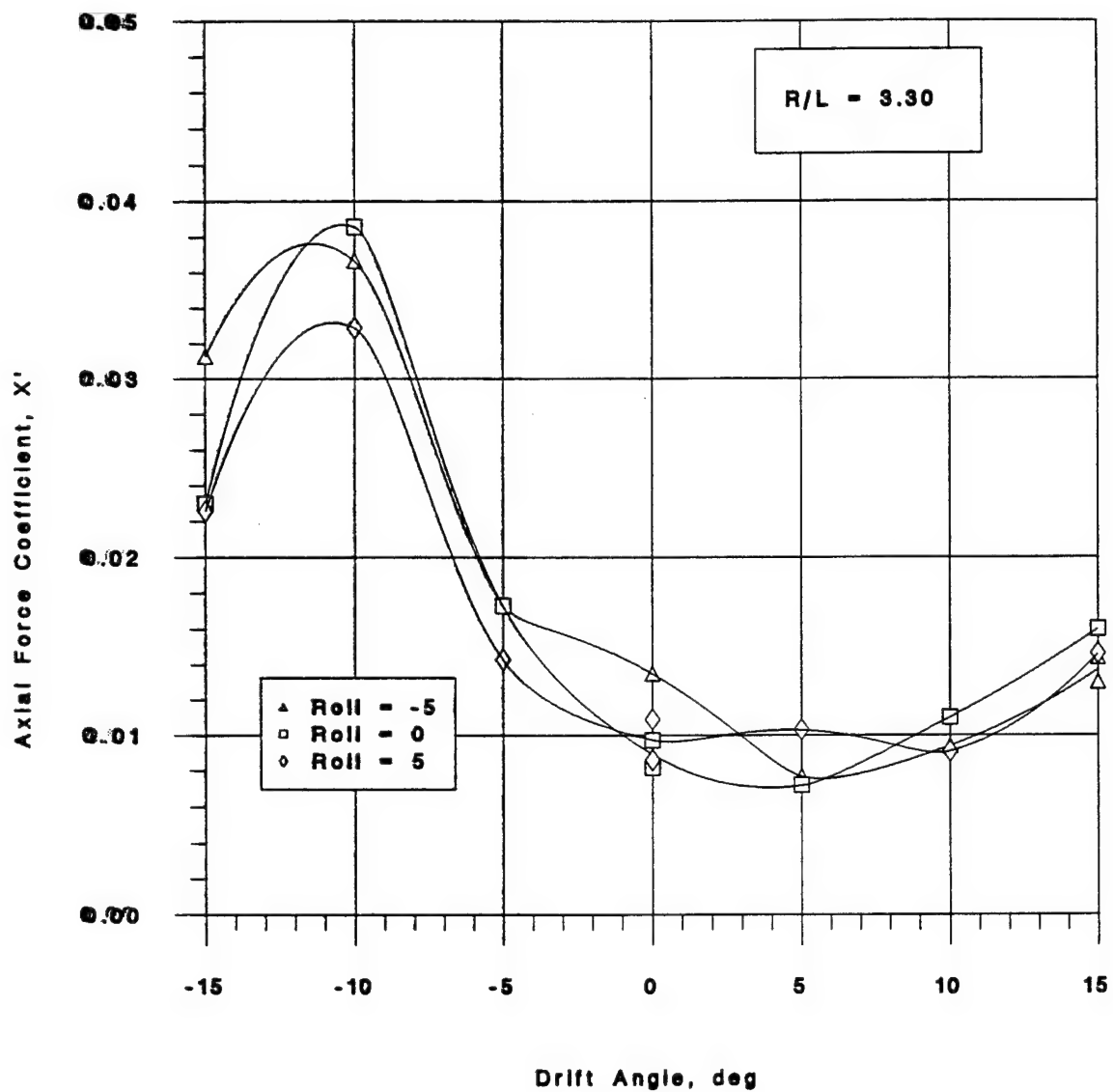
Figure 24. Behavior of Axial Force with Drift and Roll Angles at 10 Knots
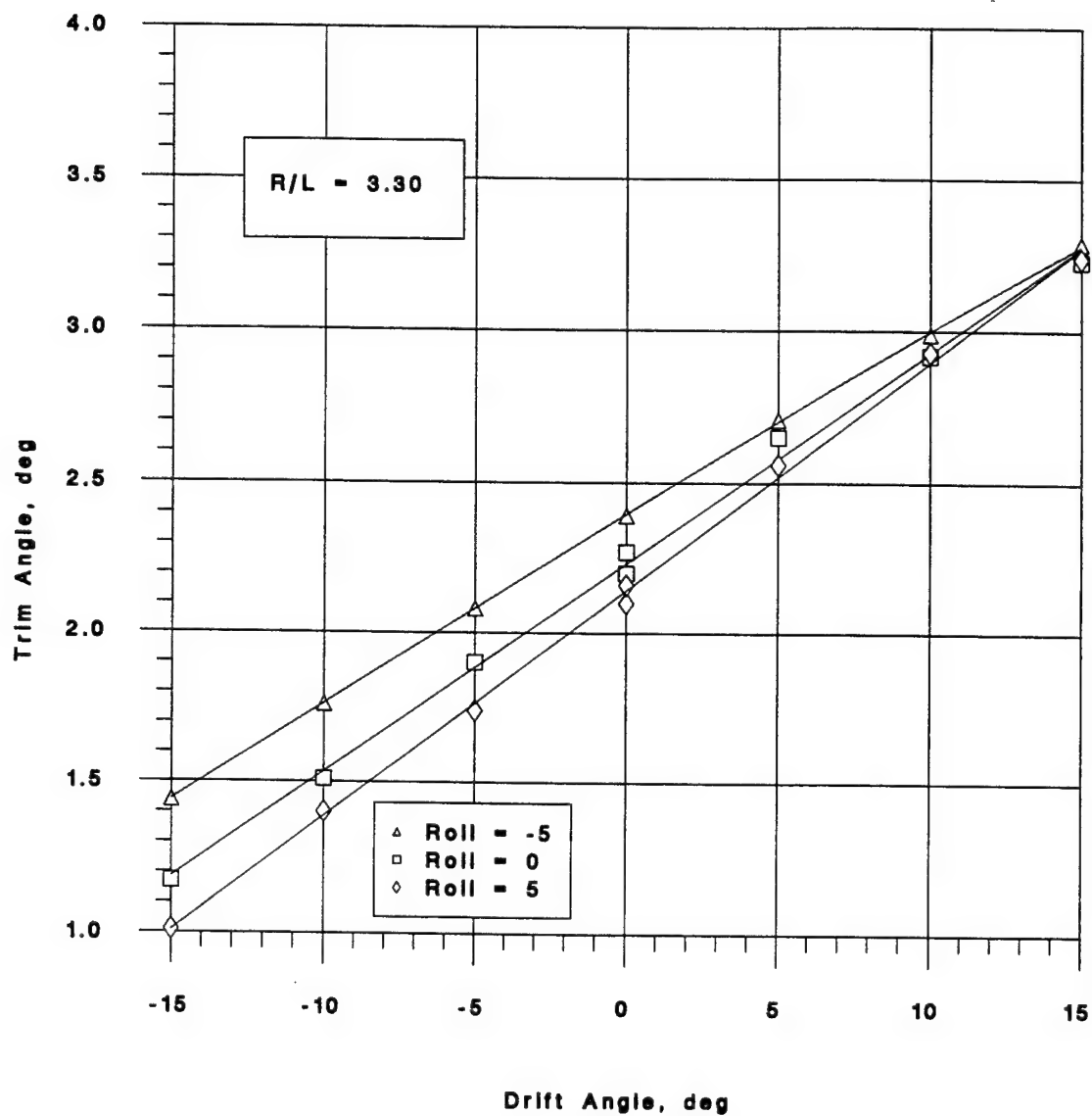
Figure 25.   Behavior of Trim Angle with Drift and
Roll Angles at 10 Knots

52
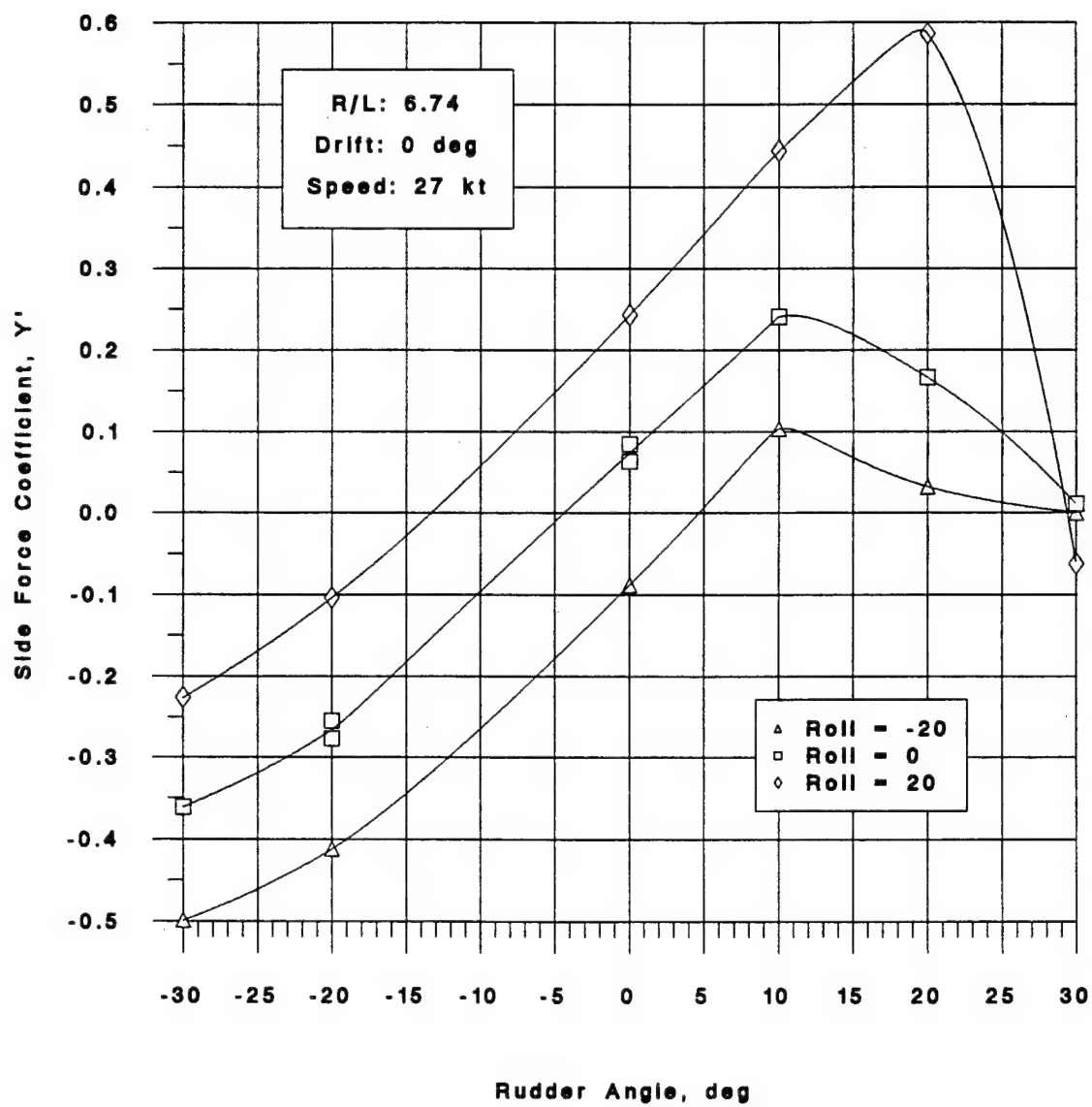
Figure 26. Behavior of Side Force with Rudder Angle at 27 Knots

53
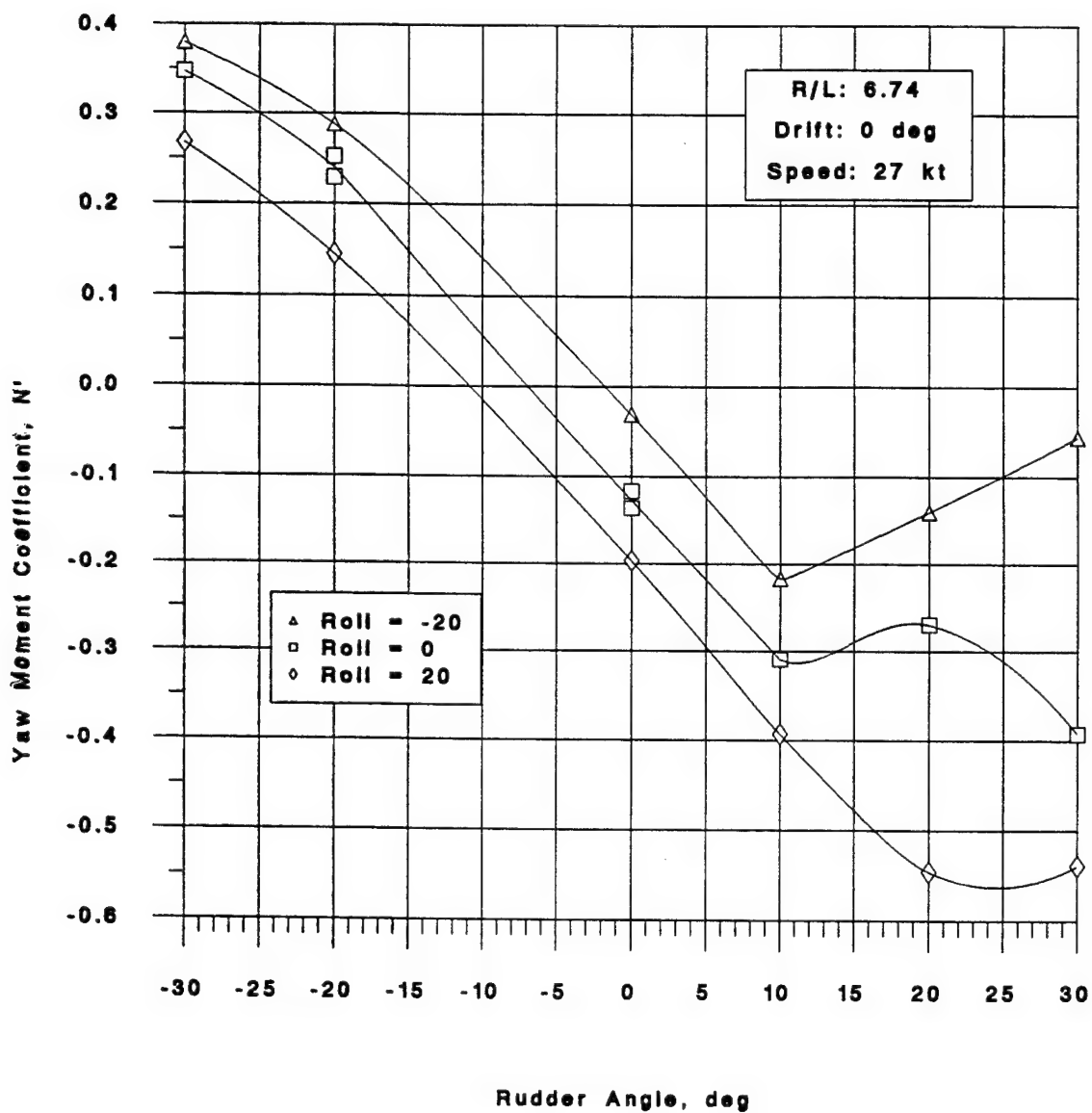
Figure 27.   Behavior of Yaw Moment with Rudder
Angle at 27 knots
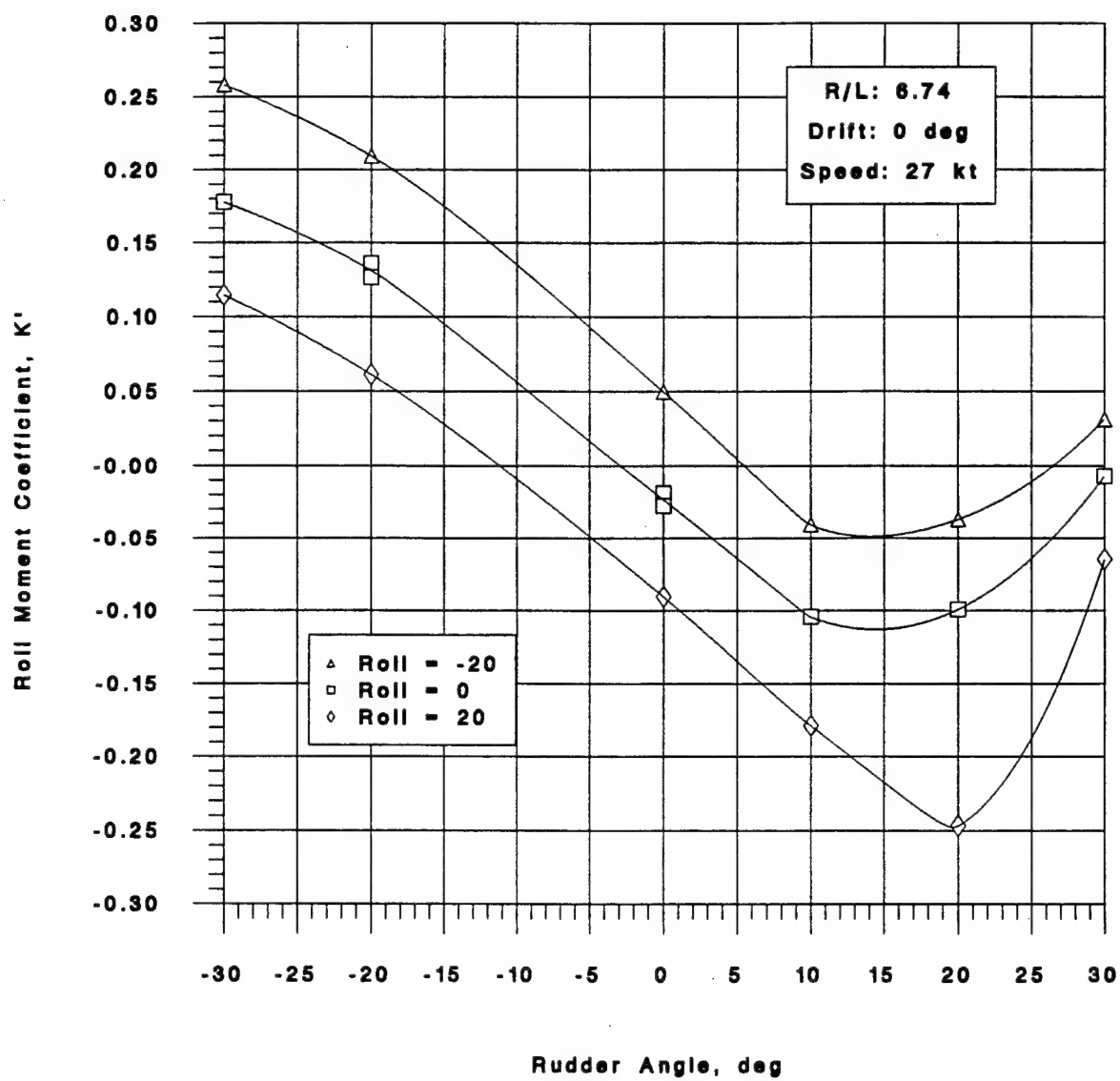
Figure 28. Behavior of Roll Moment with Rudder
Angle at 27 Knots

55
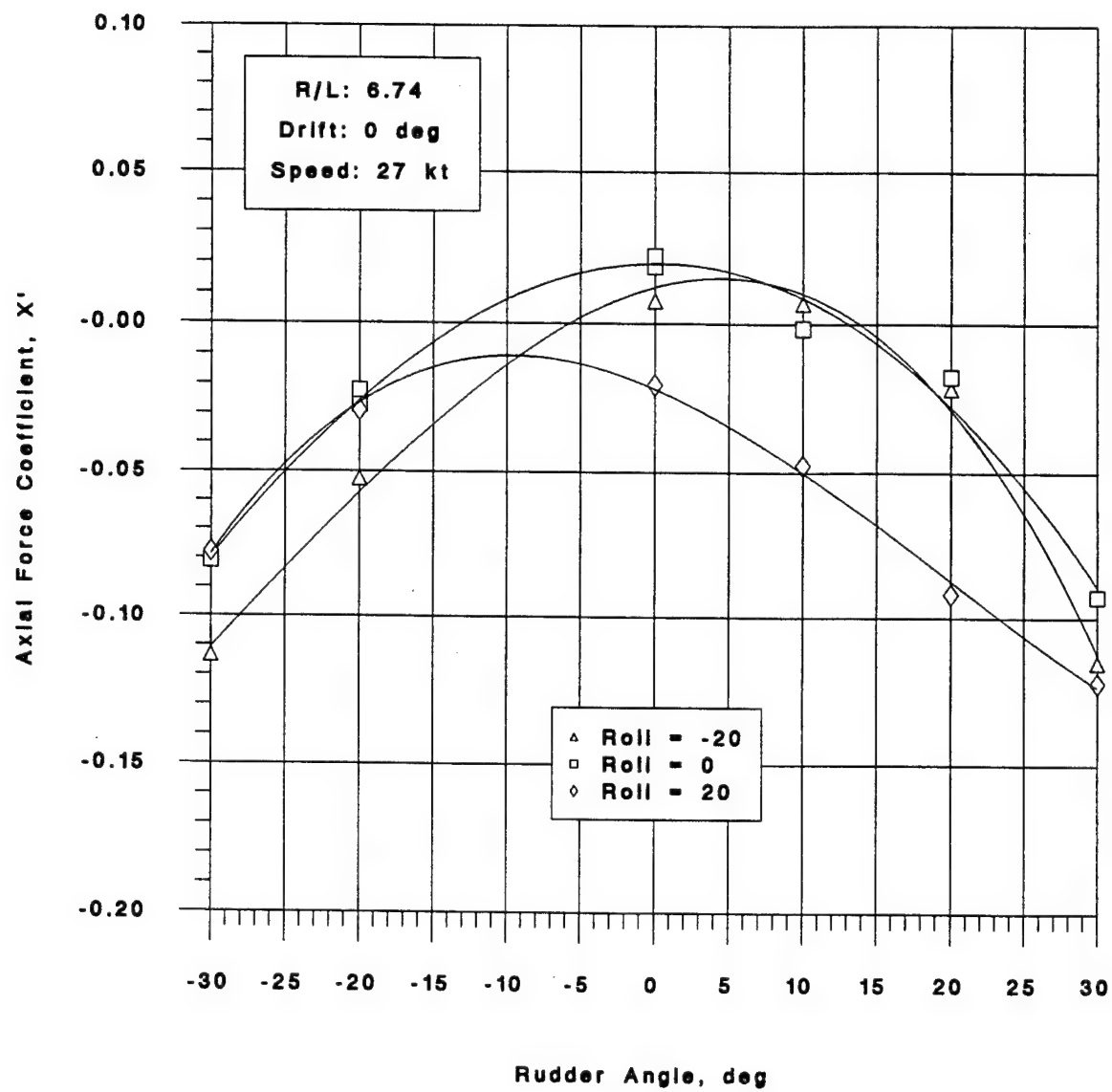
Figure 29.   Behavior of Axial Force with Rudder
              Angle at 27 Knots

56
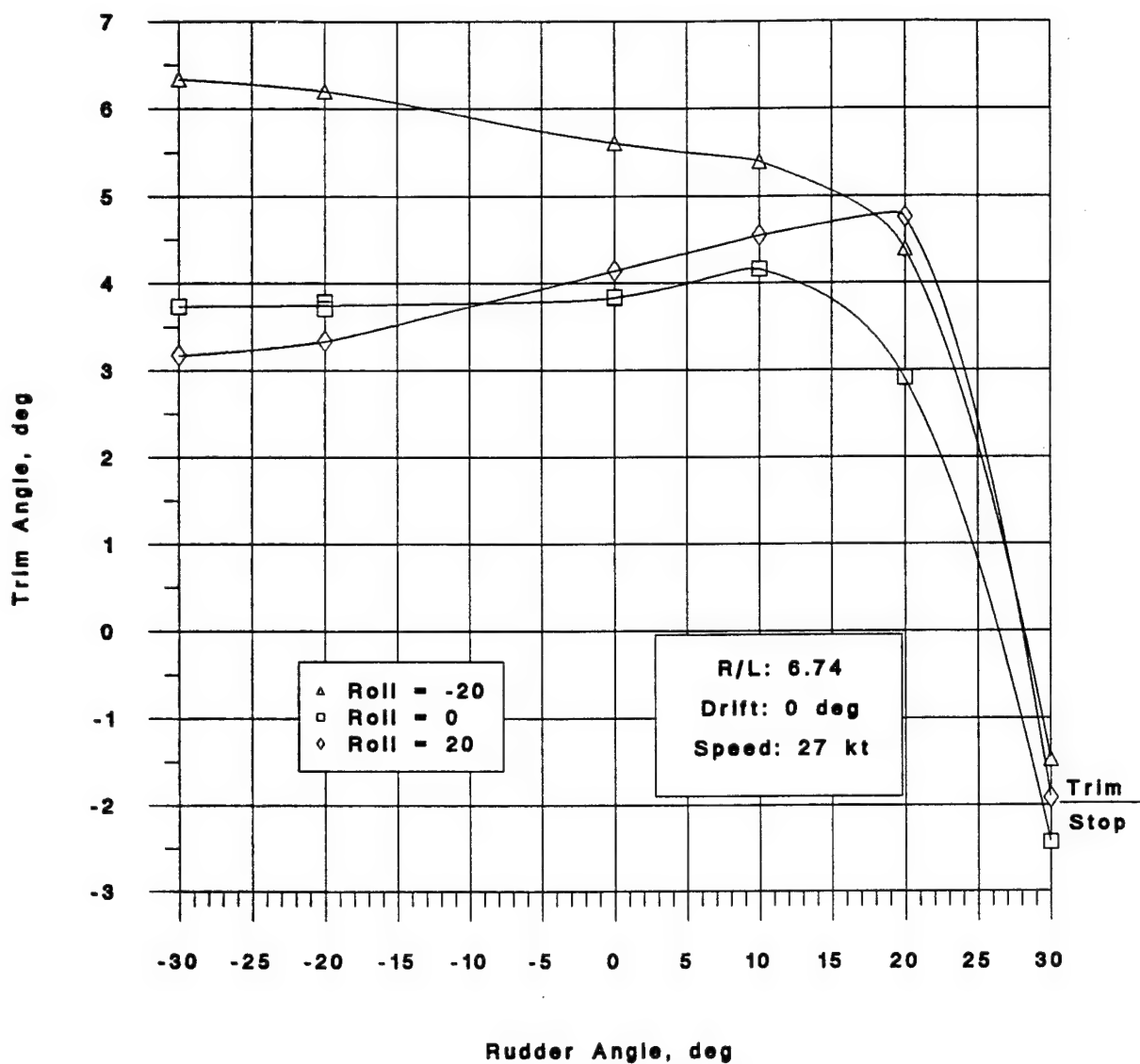
Figure 30.   Effect of Rudder Angle on Trim at 27
                     Knots
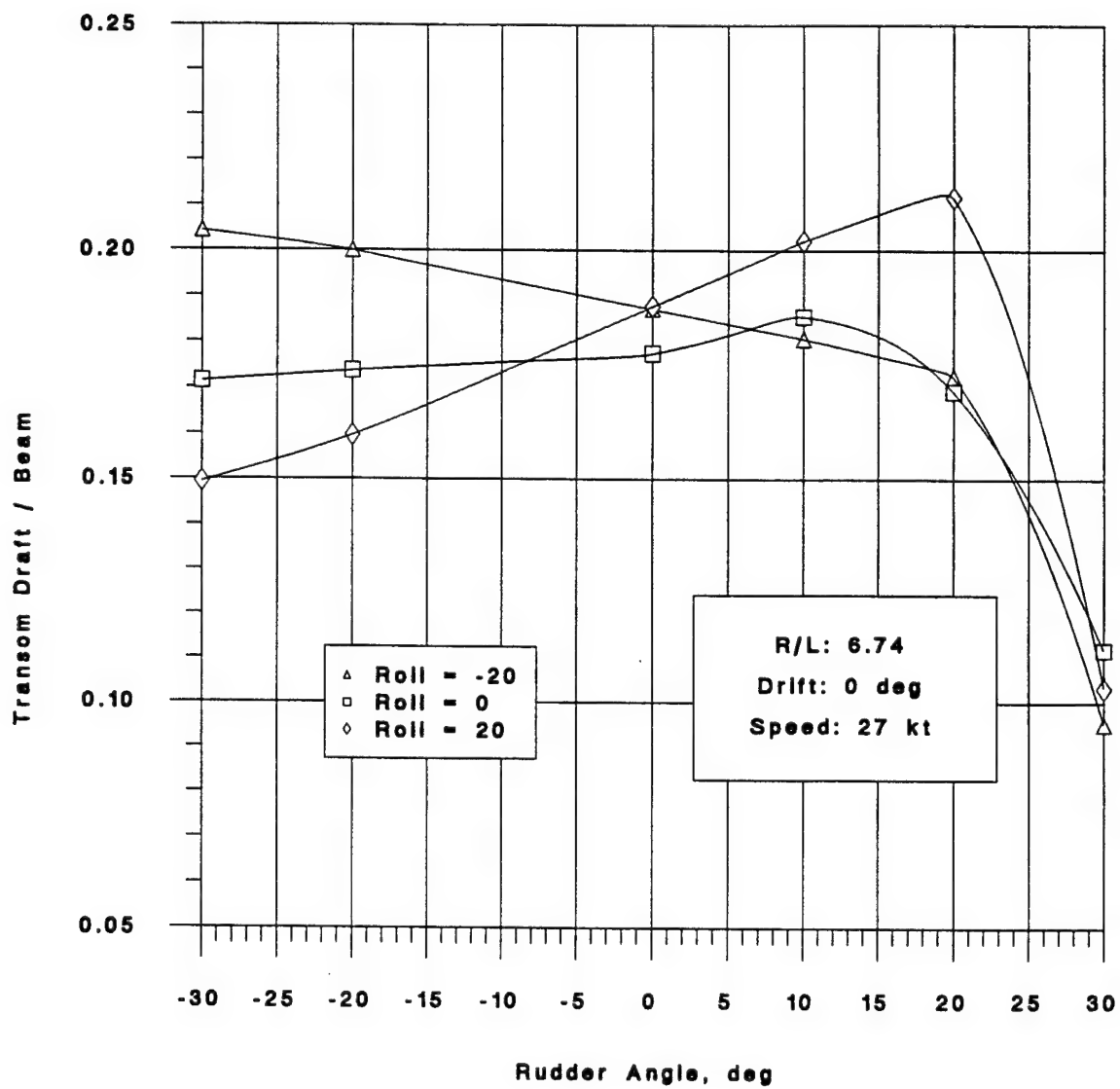
Figure 31.   Effect of Rudder Angle on Transom Draft
at 27 Knots
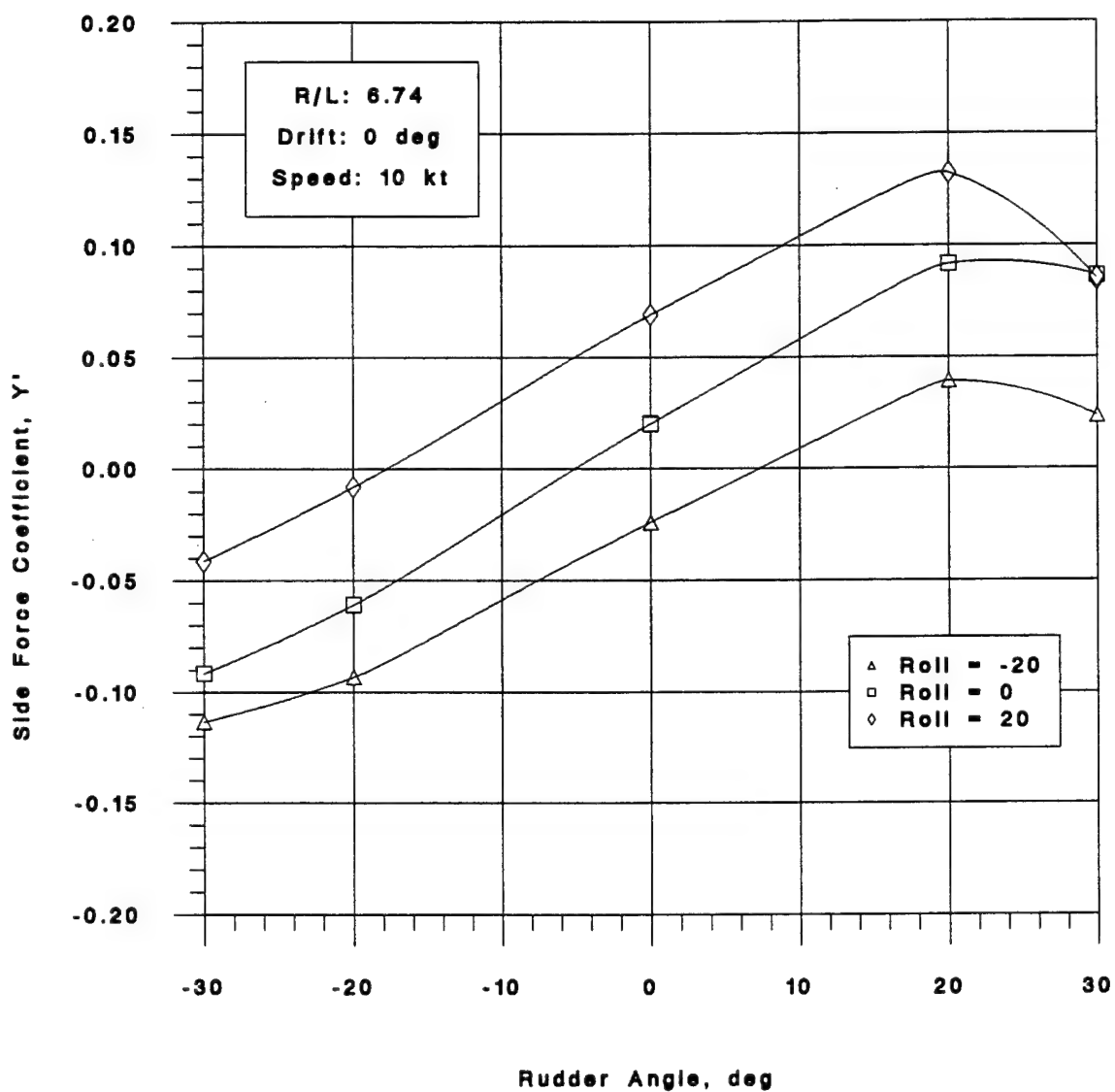
Figure 32.   Behavior of Side Force with Rudder
Angle at 10 Knots
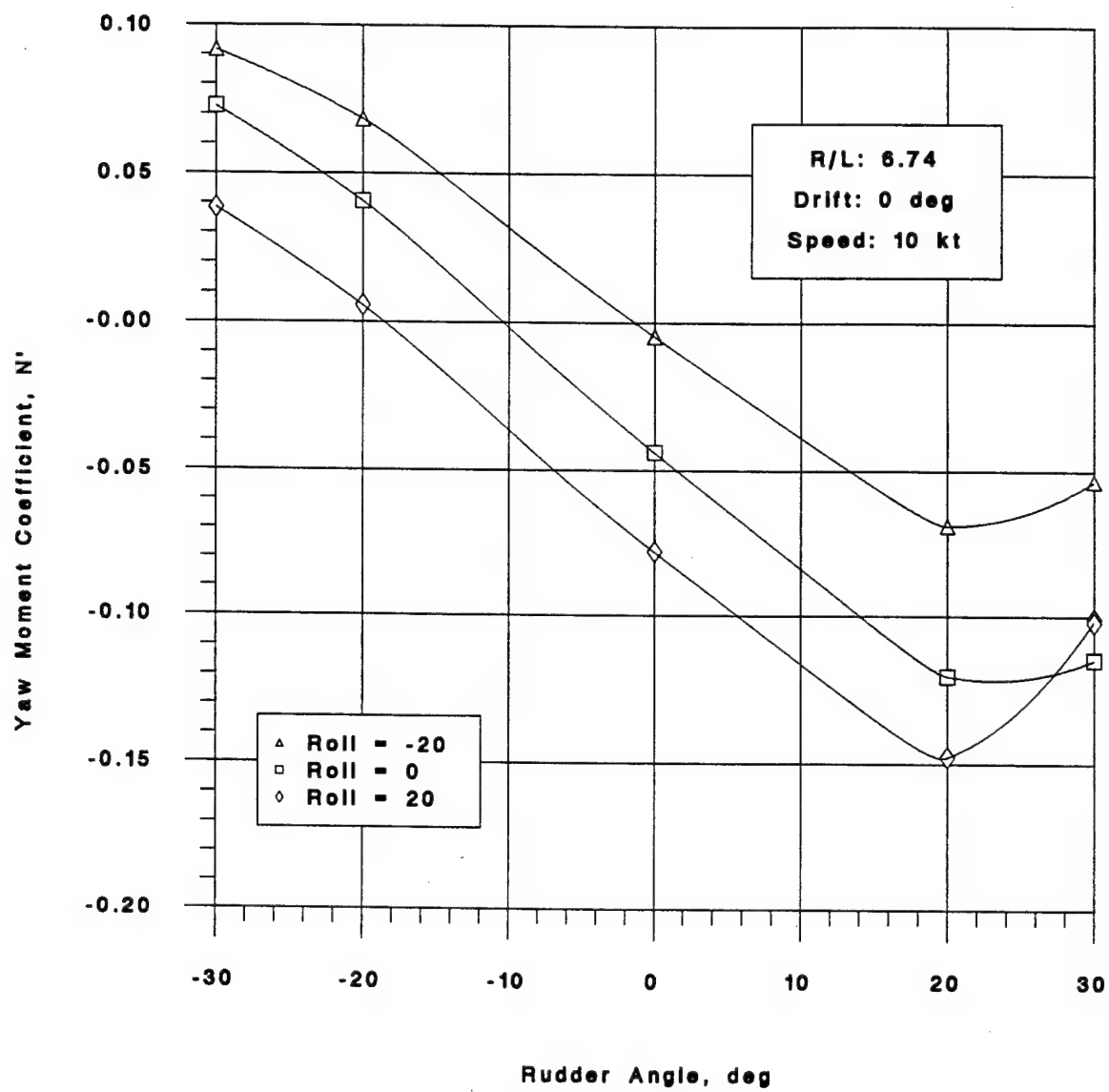
Figure 33.   Behavior of Yaw Moment with Rudder
Angle at 10 Knots
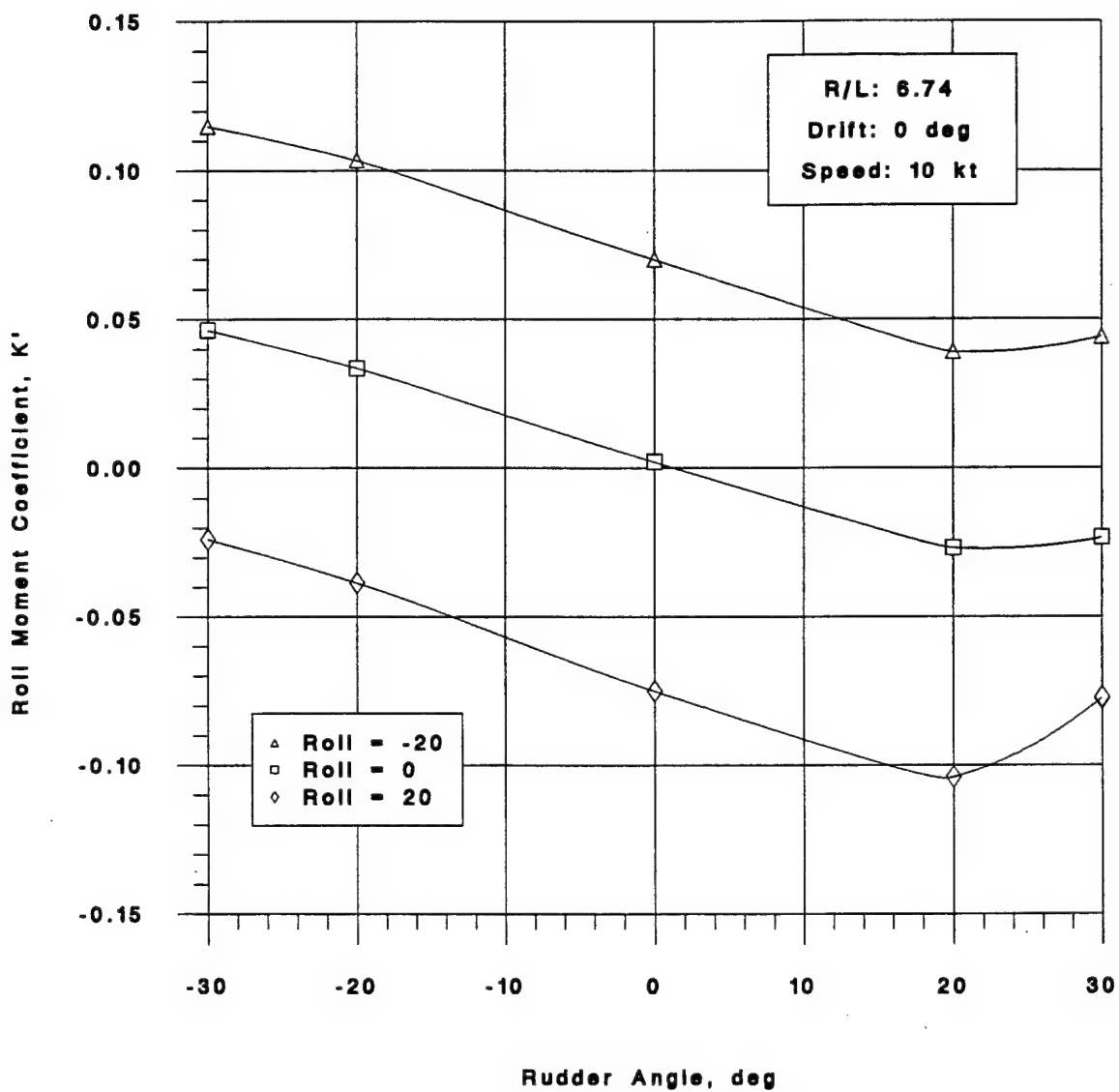
Figure 34.   Behavior of Roll Moment with Rudder
Angle at 10 knots
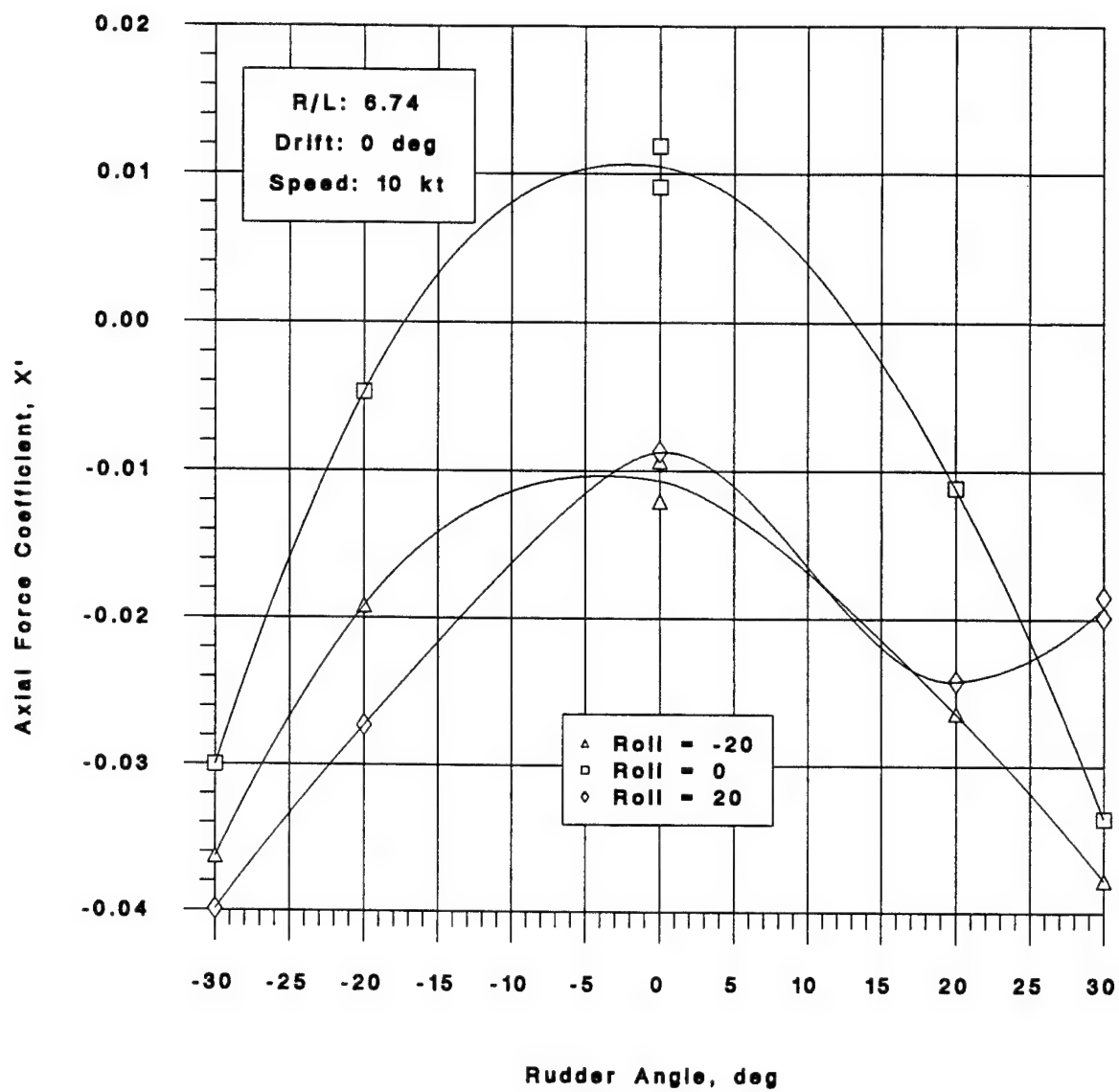
Figure 35. Behavior of Axial Force with Rudder Angle at 10 Knots
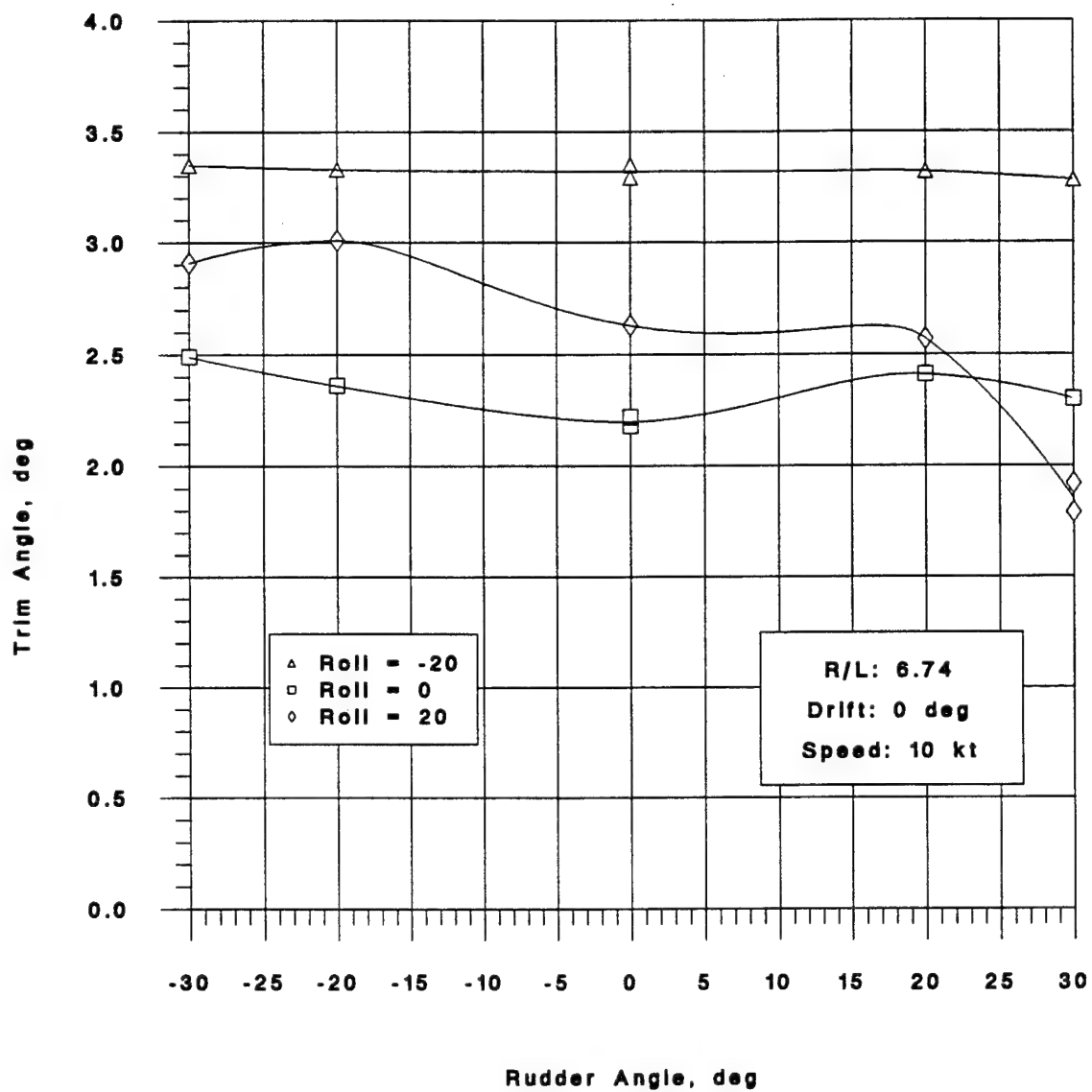
Figure 36.   Behavior of Trim Angle with Rudder
Angle at 10 Knots

[BLANK]

APPENDIX A

CHRONOLOGICAL RUN DIRECTORY

NOTES

DR   Dummy run, used for calibration checks

DZ   Zero speed run, generally carried out with
     the model in the water to obtain zero-speed
     hydrostatic characteristics

     Tabulated values are in model-scale units

[BLANK]

Run		Radius feet	Roll deg	Drift deg	Speed fps	Prop RPM
DR	1-29	Program, Instrumentation and Calibration Checks				
DZ	30	32.00	0.00	0.00	0.00	0
	31	32.00	0.00	0.00	5.59	2296
DZ	32	32.00	0.00	0.00	0.00	-1
	33	32.00	0.00	5.00	5.62	2299
	34	32.00	0.00	10.00	5.62	2292
	35	32.00	0.00	15.00	5.62	2289
	36	32.00	0.00	-5.00	5.63	2291
	37	32.00	0.00	-10.00	5.63	2296
	38	32.00	0.00	-15.00	5.63	2312
DZ	39	32.00	5.00	0.00	0.00	0
	40	32.00	5.00	0.00	5.62	2315
	41	32.00	5.00	5.00	5.61	2320
DR	42	32.00	5.00	5.00	0.00	0
	43	32.00	5.00	10.00	5.62	2315
	44	32.00	5.00	15.00	5.62	2308
	45	32.00	5.00	-5.00	5.62	2322
	46	32.00	5.00	-10.00	5.62	2312
	47	32.00	5.00	-15.00	5.62	2311
DR	48	32.00	-5.00	0.00	0.00	4
DZ	49	32.00	-5.00	0.00	0.00	0
	50	32.00	-5.00	0.00	5.62	2308
	51	32.00	-5.00	5.00	5.63	2307
	52	32.00	-5.00	10.00	5.62	2303
	53	32.00	-5.00	15.00	5.62	2299
DZ	64	32.00	-5.00	0.00	0.00	0
	65	32.00	-5.00	0.00	5.63	2300
	66	32.00	-5.00	5.00	5.62	2303
	68	32.00	-5.00	10.00	5.62	2304
	69	32.00	-5.00	15.00	5.62	2300
	70	32.00	-5.00	-5.00	5.62	2309
	71	32.00	-5.00	-10.00	5.63	2305
DR	72	32.00	-5.00	-10.00	0.00	2355
DR	73	32.00	-5.00	10.00	9.7	0
DR	74	32.00	-5.00	10.00	0.00	0
DR	75	32.00	-5.00	-10.00	0.00	0
DR	76	32.00	-5.00	-10.00	0.00	0
DZ	77	32.00	-5.00	-10.00	0.00	0
	78	32.00	-5.00	10.00	5.63	2261
	79	32.00	-5.00	10.00	5.62	2298
	80	32.00	-5.00	15.00	5.62	2306
	81	32.00	-5.00	0.00	5.62	2309
	83	32.00	-5.00	-15.00	5.61	2314
DR	84	32.00	0.00	15.00	15.21	3680
DR	86	32.00	0.00	15.00	15.19	4293
	87	32.00	-5.00	5.00	5.60	2313
	88	32.00	-5.00	-5.00	5.59	2314
	89	32.00	-5.00	-10.00	5.60	2306
DZ	90	32.00	5.00	0.00	0.00	0
	91	32.00	5.00	0.00	5.62	2313

Run		Radius feet	Roll deg	Drift deg	Speed fps	Prop RPM
	92	32.00	5.00	15.00	5.62	2306
	93	32.00	5.00	-15.00	5.62	2309
	94	32.00	5.00	-10.00	5.63	2309
	95	32.00	5.00	10.00	5.62	2313
	96	32.00	5.00	5.00	5.62	2313
	97	32.00	5.00	-5.00	5.63	2314
DZ	98	32.00	0.00	0.00	0.00	0
	99	32.00	0.00	0.00	5.61	2316
	100	32.00	0.00	5.00	5.61	2317
	101	32.00	0.00	10.00	5.62	2315
	102	32.00	0.00	15.00	5.63	2306
	103	32.00	0.00	-5.00	5.62	2311
	104	32.00	0.00	-10.00	5.62	2312
	105	32.00	0.00	-15.00	5.62	2321
DR	106	32.00	0.00	-15.00	0.00	4803
DR	107	32.00	0.00	-15.00	0.00	4419
DZ	108	32.00	0.00	0.00	0.00	1
	109	32.00	0.00	0.00	15.20	4517
	110	32.00	0.00	0.00	15.17	4428
	111	32.00	0.00	5.00	15.18	4424
	112	32.00	0.00	10.00	15.18	4394
	113	32.00	0.00	15.00	15.18	4366
	114	32.00	0.00	15.00	15.22	4407
	115	32.00	0.00	-5.00	15.19	4497
	116	32.00	0.00	-5.00	15.21	4441
	117	32.00	0.00	-10.00	15.21	4464
	118	32.00	0.00	-15.00	15.20	4485
DZ	128	32.00	0.00	0.00	0.00	0
	129	32.00	0.00	0.00	15.20	4378
	130	32.00	0.00	0.00	15.20	4441
	131	32.00	0.00	15.00	15.21	4394
DR	132	32.00	0.00	15.00	0.00	0
	133	32.00	0.00	0.00	15.16	4418
DR	134	32.00	0.00	0.00	0.00	-1
DR	135	32.00	0.00	0.00	0.00	-1
	136	32.00	10.00	-15.00	15.20	4427
DR	137	32.00	20.00	-15.00	0.00	0
DZ	138	32.00	20.00	-15.00	0.00	0
	139	32.00	20.00	-15.00	15.21	4397
DR	140	32.00	35.00	-15.00	0.00	0
DZ	141	32.00	35.00	-15.00	0.00	0
	142	32.00	35.00	-15.00	15.21	4376
DR	143	32.00	35.00	-15.00	0.00	3
DZ	144	32.00	-35.00	-15.00	0.00	0
	145	32.00	-35.00	-15.00	15.20	4406
DR	146	32.00	-35.00	-15.00	0.00	0
DZ	147	32.00	10.00	0.00	0.00	0
	148	32.00	10.00	0.00	15.19	4466
	149	32.00	10.00	5.00	15.21	4342
	150	32.00	10.00	10.00	15.18	4350
	151	32.00	10.00	15.00	15.18	4326

Run		Radius feet	Roll deg	Drift deg	Speed fps	Prop RPM
	152	32.00	10.00	-5.00	15.18	4405
	153	32.00	10.00	-10.00	15.20	4415
	154	32.00	10.00	0.00	15.21	4374
	155	32.00	10.00	-15.00	15.21	4422
DR	156	32.00	20.00	0.00	0.00	0
DR	157	32.00	20.00	0.00	0.00	4449
DZ	158	32.00	20.00	0.00	0.00	0
	159	32.00	20.00	0.00	15.18	4369
	160	32.00	20.00	5.00	15.21	4377
	161	32.00	20.00	10.00	15.21	4368
	162	32.00	20.00	15.00	15.21	4325
	163	32.00	20.00	-5.00	15.21	4395
	164	32.00	20.00	-10.00	15.19	4447
	165	32.00	20.00	-15.00	15.19	4415
	176	32.00	0.00	0.00	15.20	4406
DZ	177	32.00	0.00	0.00	0.00	0
	178	32.00	0.00	0.00	15.19	4394
	179	32.00	0.00	0.00	15.19	4531
	180	32.00	0.00	0.00	15.18	4411
DR	181	32.00	0.00	0.00	0.00	-2
DR	182	32.00	0.00	0.00	0.00	4472
DZ	183	32.00	35.00	0.00	0.00	0
	184	32.00	35.00	0.00	15.22	4388
	185	32.00	35.00	5.00	15.22	4396
	186	32.00	35.00	10.00	15.20	4385
	187	32.00	35.00	15.00	15.20	4362
	188	32.00	35.00	-5.00	15.18	4389
	189	32.00	35.00	-10.00	15.22	4393
	190	32.00	35.00	-15.00	15.21	4389
	191	32.00	35.00	5.00	15.19	4330
DR	192	32.00	-10.00	0.00	0.00	2774
DR	193	32.00	-10.00	0.00	0.00	4425
DZ	194	32.00	-10.00	0.00	0.00	4
	195	32.00	-10.00	0.00	15.19	4362
	196	32.00	-10.00	5.00	15.21	4368
	197	32.00	-10.00	10.00	15.20	4355
	198	32.00	-10.00	15.00	15.18	4346
	199	32.00	-10.00	-5.00	15.17	4366
	200	32.00	-10.00	-10.00	15.18	4375
	201	32.00	-10.00	-15.00	15.20	4367
	202	32.00	-10.00	15.00	15.18	4347
DR	203	32.00	-10.00	15.00	0.00	4
DR	204	32.00	-10.00	0.00	0.00	4426
DZ	205	32.00	-10.00	0.00	0.00	-1
	206	32.00	-10.00	0.00	15.20	4360
	207	32.00	-10.00	5.00	15.20	4357
	208	32.00	-10.00	10.00	15.22	4357
	209	32.00	-10.00	15.00	15.20	4340
	210	32.00	-10.00	-15.00	15.18	4371
DR	211	32.00	-20.00	0.00	0.00	0
DR	212	32.00	-20.00	0.00	0.00	4410

Run		Radius feet	Roll deg	Drift deg	Speed fps	Prop RPM	
DZ	213	32.00	-20.00	0.00	0.00	0	
	214	32.00	-20.00	0.00	15.20	4333	
	215	32.00	-20.00	5.00	15.20	4326	
	216	32.00	-20.00	10.00	15.20	4344	
	217	32.00	-20.00	15.00	15.17	4325	
	218	32.00	-20.00	-5.00	15.16	4348	
	219	32.00	-20.00	-10.00	15.21	4373	
	220	32.00	-20.00	-15.00	15.21	4366	
	221	32.00	-20.00	15.00	15.19	4350	
DR	222	32.00	-20.00	15.00	0.00	0	
DR	223	32.00	-35.00	0.00	0.00	0	
DR	224	32.00	-35.00	0.00	0.00	4451	
DZ	225	32.00	-35.00	0.00	0.00	-1	
	226	32.00	-35.00	0.00	15.19	4348	
	227	32.00	-35.00	15.00	15.20	4424	
	242	32.00	0.00	0.00	15.22	4424	
DR	243	32.00	-35.00	0.00	0.00	1	
DZ	244	32.00	-35.00	0.00	0.00	0	
	245	32.00	-35.00	0.00	15.17	4406	
	246	32.00	-35.00	5.00	15.18	4418	
	247	32.00	-35.00	10.00	15.20	4454	
	248	32.00	-35.00	15.00	15.20	4468	
	249	32.00	-35.00	-5.00	15.20	4410	
	250	32.00	-35.00	-10.00	15.21	4464	
	251	32.00	-35.00	-15.00	15.19	4479	
	252	32.00	-35.00	-7.00	15.20	4411	
DR	253	32.00	20.00	0.00	0.00	4491	
DZ	254	32.00	20.00	0.00	0.00	0	
	255	32.00	20.00	0.00	15.21	4432	
	256	32.00	20.00	15.00	15.20	4411	
	257	32.00	20.00	-15.00	15.18	4476	
DR	258	32.00	0.00	0.00	0.00	4476	
DR	259	32.00	0.00	0.00	0.00	0	
DZ	260	32.00	0.00	0.00	0.00	0	

			*Rudder Deflection Tests**				Rudder deg
	261	32.00	0.00	0.00	15.18	4431	0
	262	32.00	0.00	0.00	15.17	4433	-20
	263	32.00	0.00	0.00	15.18	4437	0
	264	32.00	0.00	0.00	15.20	4424	-20
	265	32.00	0.00	0.00	15.20	4439	-30
	266	32.00	0.00	0.00	15.22	4420	20
	268	32.00	0.00	0.00	15.19	4421	30
	269	32.00	0.00	0.00	15.19	4416	10
DR	270	32.00	0.00	0.00	0.00	0	
DR	271	32.00	20.00	0.00	0.00	0	
DZ	272	32.00	20.00	0.00	0.00	0	
	273	32.00	20.00	0.00	15.21	4434	10
	274	32.00	20.00	0.00	15.18	4442	0
DR	275	32.00	20.00	0.00	4.37	0	

	Run	Radius feet	Roll deg	Drift deg	Speed fps	Prop RPM	Rudder deg
	276	32.00	20.00	0.00	15.20	4422	20
	277	32.00	20.00	0.00	15.20	4417	30
	278	32.00	20.00	0.00	15.19	4424	-20
	279	32.00	20.00	0.00	15.20	4407	-30
DR	280	32.00	20.00	0.00	0.00	0	
DR	281	32.00	-20.00	0.00	0.00	4484	
DR	282	32.00	-20.00	0.00	5.28	0	
	283	32.00	-20.00	0.00	15.21	4394	0
	284	32.00	-20.00	0.00	15.21	4392	20
	285	32.00	-20.00	0.00	15.20	4438	30
	286	32.00	-20.00	0.00	15.20	4377	-20
	287	32.00	-20.00	0.00	15.20	4361	-30
	288	32.00	-20.00	0.00	15.20	4357	10
DR	289	32.00	-20.00	0.00	0.00	0	
DR	297	32.00	0.00	0.00	0.00	0	
DR	298	32.00	0.00	0.00	0.00	2377	
DZ	299	32.00	0.00	0.00	0.00	1	
	300	32.00	0.00	0.00	5.62	2367	0
	301	32.00	0.00	0.00	5.62	2331	0
	302	32.00	0.00	0.00	5.62	2317	0
	303	32.00	0.00	0.00	5.62	2313	20
	304	32.00	0.00	0.00	5.63	2314	30
	305	32.00	0.00	0.00	5.61	2324	-20
	306	32.00	0.00	0.00	5.62	2316	-30
DR	307	32.00	20.00	0.00	0.00	2333	
DZ	308	32.00	20.00	0.00	0.00	0	
	309	32.00	20.00	0.00	5.63	2320	-30
	310	32.00	20.00	0.00	5.63	2321	-20
	311	32.00	20.00	0.00	5.63	2317	0
	312	32.00	20.00	0.00	5.62	2315	20
	313	32.00	20.00	0.00	5.62	2320	30
	314	32.00	20.00	0.00	5.62	2316	30
DR	315	32.00	20.00	0.00	0.00	0	
DR	316	32.00	-20.00	0.00	0.00	2324	
DZ	317	32.00	-20.00	0.00	0.00	0	
	318	32.00	-20.00	0.00	5.62	2317	30
	319	32.00	-20.00	0.00	5.63	2313	20
	320	32.00	-20.00	0.00	5.63	2313	0
	321	32.00	-20.00	0.00	5.63	2320	-20
	322	32.00	-20.00	0.00	5.63	2316	-30
	323	32.00	-20.00	0.00	5.62	2326	0
DR	324	32.00	-20.00	0.00	0.00	1	

End Rudder Deflection Tests

DR 325-378 Air Tare Tests, 32 ft Radius

	Run	Radius feet	Roll deg	Drift deg	Speed fps	Prop RPM	Rudder deg
	379	15.67	0.00	0.00	5.63	2295	
DZ	380	15.67	0.00	5.00	0.00	1	
	381	15.67	0.00	5.00	5.61	2322	
	382	15.67	0.00	10.00	5.61	2326	
	383	15.67	0.00	15.00	5.61	2324	

Run		Radius feet	Roll deg	Drift deg	Speed fps	Prop RPM
	384	15.67	0.00	-5.00	5.62	2325
	385	15.67	0.00	-10.00	5.62	2343
	386	15.67	0.00	-15.00	5.61	2331
	387	15.67	0.00	0.00	5.61	2328
DR	388	15.67	0.00	0.00	0.00	-1
DR	389	15.67	5.00	0.00	0.00	2337
DZ	390	15.67	5.00	0.00	0.00	0
	391	15.67	5.00	0.00	5.62	2331
	392	15.67	5.00	5.00	5.61	2341
DR	393	15.67	5.00	5.00	15.15	2360
DR	394	15.67	5.00	10.00	15.13	2341
DR	395	15.67	5.00	10.00	5.61	2327
DR	396	15.67	5.00	10.00	15.16	2341
DR	397	15.67	5.00	10.00	0.00	1
DR	398	15.67	5.00	10.00	0.00	1
	399	15.67	5.00	10.00	5.62	2327
	400	15.67	5.00	15.00	5.62	2332
	401	15.67	5.00	-5.00	5.62	2329
	402	15.67	5.00	-10.00	5.60	2331
	403	15.67	5.00	-15.00	5.60	2331
	404	15.67	5.00	0.00	5.62	2333
DR	405	15.67	5.00	0.00	0.00	0
DR	406	15.67	-5.00	0.00	0.00	2346
DZ	407	15.67	-5.00	0.00	0.00	0
	408	15.67	-5.00	0.00	5.62	2331
	409	15.67	-5.00	5.00	5.61	2327
	410	15.67	-5.00	10.00	5.61	2324
	411	15.67	-5.00	15.00	5.62	2325
	412	15.67	-5.00	-5.00	5.61	2325
	413	15.67	-5.00	-10.00	5.62	2324
	414	15.67	-5.00	-15.00	5.62	2325
	415	15.67	-5.00	15.00	5.62	2325
DR	416	15.67	0.00	0.00	0.00	4196
DR	417	15.67	0.00	0.00	0.00	4648
DR	418	15.67	0.00	0.00	0.00	4432
DR	419	15.67	0.00	0.00	0.00	4427
	429	15.67	0.00	0.00	15.15	4386
	430	15.67	0.00	0.00	15.16	4742
	431	15.67	0.00	0.00	15.18	4499
	432	15.67	0.00	0.00	15.17	4436
	433	15.67	0.00	0.00	15.17	4433
	434	15.67	0.00	0.00	15.17	4407
DR	435	15.67	0.00	0.00	0.00	4482
	436	15.67	0.00	5.00	15.15	4407
	437	15.67	0.00	10.00	15.17	4400
	438	15.67	0.00	15.00	15.14	4366
	439	15.67	0.00	-5.00	15.19	4417
	440	15.67	0.00	-10.00	15.16	4424
	441	15.67	0.00	-15.00	15.16	4445

Run		Radius feet	Roll deg	Drift deg	Speed fps	Prop RPM
	442	15.67	0.00	15.00	15.14	4388
DR	443	15.67	0.00	15.00	0.00	0
DR	44	15.67	10.00	0.00	0.00	4495
DZ	445	15.67	10.00	0.00	0.00	1
	446	15.67	10.00	0.00	15.19	4423
	447	15.67	10.00	5.00	15.16	4402
	448	15.67	10.00	10.00	15.17	4410
	449	15.67	10.00	15.00	15.13	4408
DR	450	15.67	10.00	15.00	0.00	0
DR	451	15.67	10.00	0.00	0.00	0
	452	15.67	10.00	-5.00	15.17	4415
	453	15.67	10.00	-10.00	15.18	4433
	454	15.67	10.00	-15.00	15.19	4430
	455	15.67	10.00	5.00	15.18	4412
DR	456	15.67	20.00	0.00	0.00	4538
DZ	457	15.67	20.00	0.00	0.00	0
	458	15.67	20.00	0.00	15.15	4438
	459	15.67	20.00	5.00	15.21	4411
	460	15.67	20.00	10.00	15.16	4405
	461	15.67	20.00	15.00	15.19	4392
	462	15.67	20.00	-5.00	15.17	4434
	463	15.67	20.00	-10.00	15.20	4449
	464	15.67	20.00	-15.00	15.15	4455
	465	15.67	20.00	-15.00	15.17	4442
DR	466	15.67	35.00	0.00	0.00	4502
DR	467	15.67	35.00	0.00	0.00	0
	468	15.67	35.00	0.00	15.16	4416
	469	15.67	35.00	0.00	15.17	4447
	470	15.67	35.00	5.00	15.17	4410
	471	15.67	35.00	10.00	15.16	4404
	472	15.67	35.00	15.00	15.17	4410
	473	15.67	35.00	-5.00	15.14	4449
	474	15.67	35.00	-10.00	15.19	4433
	475	15.67	35.00	-15.00	15.14	4440
	476	15.67	35.00	-10.00	15.18	4433
DR	477	15.67	35.00	-10.00	0.00	0
DR	478	15.67	35.00	0.00	0.00	1
DR	479	15.67	-10.00	0.00	0.00	4522
DR	480	15.67	-10.00	0.00	0.00	4509
DR	481	15.67	-10.00	0.00	0.00	0
DZ	482	15.67	-10.00	0.00	0.00	0
	483	15.67	-10.00	0.00	15.19	4409
	484	15.67	-10.00	15.00	15.17	4387
DR	496	15.67	-10.00	5.00	0.00	4483
DZ	497	15.67	-10.00	5.00	0.00	0
	498	15.67	-10.00	5.00	15.15	4400
	499	15.67	-10.00	10.00	15.16	4399
	500	15.67	-10.00	15.00	15.16	4396
	501	15.67	-10.00	-5.00	15.20	4418
	502	15.67	-10.00	-10.00	15.18	4425
	503	15.67	-10.00	-15.00	15.16	4438

Run		Radius feet	Roll deg	Drift deg	Speed fps	Prop RPM
	504	15.67	-10.00	0.00	15.15	4415
DZ	505	15.67	-10.00	0.00	0.00	0
DR	506	15.67	-10.00	0.00	0.00	0
DR	507	15.67	-20.00	0.00	0.00	4486
DZ	508	15.67	-20.00	0.00	0.00	0
	509	15.67	-20.00	0.00	15.21	4416
	510	15.67	-20.00	5.00	15.16	4406
	511	15.67	-20.00	10.00	15.19	4402
	512	15.67	-20.00	15.00	15.14	4392
	513	15.67	-20.00	-5.00	15.20	4414
	514	15.67	-20.00	-10.00	15.16	4411
	515	15.67	-20.00	-15.00	15.18	4402
	516	15.67	-20.00	15.00	15.17	4389
DR	517	15.67	-20.00	15.00	0.00	0
DR	518	15.67	-35.00	0.00	0.00	0
DR	519	15.67	-35.00	0.00	0.00	0
DR	520	15.67	-35.00	0.00	0.00	4487
DR	521	15.67	-35.00	0.00	0.00	0
DZ	522	15.67	-35.00	0.00	0.00	0
	523	15.67	-35.00	0.00	15.15	4412
	524	15.67	-35.00	5.00	15.19	4426
	525	15.67	-35.00	10.00	15.16	4463
	526	15.67	-35.00	15.00	15.17	4481
	527	15.67	-35.00	-5.00	15.14	4406
	528	15.67	-35.00	-10.00	15.18	4482
	529	15.67	-35.00	-15.00	15.15	4494
	530	15.67	-35.00	-10.00	15.15	4485
	531	15.67	-35.00	15.00	15.13	4497
	532	15.67	-35.00	0.00	15.15	4439
DR	533	15.67	-35.00	0.00	0.00	1

DR 534-557 Air Tare Tests, 15.67 ft Radius

APPENDIX B

RAW DATA IN BALANCE AXES COORDINATE SYSTEM

Data in model-scale units. Tares have not been removed.

[BLANK]

TABLE B1   Raw Data in Balance Axes, Tares Not Removed
Model-Scale Units
Speed: 5.6 fps (10 knots) Turning Radius: 32 ft

Run no	Roll deg	Drift deg	Speed fps	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	TD in	SKWL in	Prop RPM
83	-5	-15	5.61	2.05	0.96	-11.08	2.49	-7.47	4.85	55.99	2314
89	-5	-10	5.60	2.04	1.31	-7.26	3.07	-4.29	4.68	55.73	2306
88	-5	-5	5.59	2.15	0.81	-4.33	3.09	-2.60	4.65	55.52	2314
50	-5	0	5.62	2.23	0.24	-1.57	2.63	-2.45	4.73	55.53	2308
81	-5	0	5.62	2.33	0.26	-1.46	2.94	-2.66	4.71	55.33	2309
51	-5	5	5.63	2.50	-0.28	1.20	2.43	-3.01	4.87	55.34	2307
87	-5	5	5.60	2.43	0.26	1.18	2.53	-3.12	4.77	55.30	2313
52	-5	10	5.62	2.70	-0.42	4.03	2.32	-3.05	5.02	55.27	2303
78	-5	10	5.63	2.72	-0.59	4.15	2.56	-3.16	4.94	55.12	2261
79	-5	10	5.62	2.71	-0.32	4.21	2.54	-3.21	4.95	55.14	2298
53	-5	15	5.62	2.88	-0.51	7.30	2.35	-2.66	5.16	55.22	2299
80	-5	15	5.62	2.93	-0.30	7.51	2.44	-2.90	5.17	55.15	2306
38	0	-15	5.63	1.68	1.63	-10.41	-0.99	-8.56	4.66	56.27	2312
105	0	-15	5.62	1.73	1.47	-10.66	-0.67	-9.23	4.82	56.43	2321
37	0	-10	5.63	1.88	1.17	-6.87	-0.59	-5.44	4.70	56.00	2296
104	0	-10	5.62	1.93	1.07	-6.82	-0.09	-5.85	4.71	55.95	2312
36	0	-5	5.63	2.02	0.61	-4.15	-0.58	-3.71	4.70	55.79	2291
103	0	-5	5.62	2.02	0.59	-3.80	0.02	-3.91	4.66	55.73	2311
99	0	0	5.61	2.15	0.34	-0.93	-0.09	-3.61	4.69	55.58	2316
33	0	5	5.62	2.30	0.38	2.03	-0.72	-4.13	4.72	55.40	2299
100	0	5	5.61	2.40	0.06	1.89	-0.33	-4.19	4.82	55.40	2317
34	0	10	5.62	2.64	-0.11	4.44	-0.91	-4.10	4.95	55.24	2292
101	0	10	5.62	2.77	-0.37	4.83	-0.34	-4.35	5.05	55.21	2315
35	0	15	5.62	2.82	-0.14	7.54	-0.72	-3.51	5.14	55.27	2289
102	0	15	5.63	2.84	-0.15	8.09	-0.20	-3.72	5.20	55.34	2306
47	5	-15	5.62	1.48	1.47	-9.37	-3.62	-9.50	4.59	56.46	2311
93	5	-15	5.62	1.55	1.40	-9.74	-3.58	-10.45	4.74	56.58	2309
46	5	-10	5.62	1.74	0.97	-5.99	-3.31	-6.59	4.66	56.16	2312
94	5	-10	5.63	1.79	0.96	-6.03	-3.14	-6.92	4.65	56.07	2309
45	5	-5	5.62	1.99	0.39	-3.17	-3.27	-4.91	4.70	55.83	2322
97	5	-5	5.63	2.03	0.37	-3.03	-3.03	-5.00	4.67	55.72	2314
40	5	0	5.62	2.14	0.14	-0.19	-3.33	-4.65	4.69	55.59	2315
91	5	0	5.62	2.15	0.20	-0.04	-3.15	-4.76	4.66	55.53	2313
41	5	5	5.61	2.40	-0.04	2.64	-3.50	-5.17	4.81	55.40	2320
96	5	5	5.62	2.51	-0.23	2.82	-3.29	-5.29	4.85	55.30	2313
43	5	10	5.62	2.68	-0.22	5.26	-3.69	-5.31	5.00	55.26	2315
95	5	10	5.62	2.78	-0.40	5.67	-3.38	-5.45	5.04	55.19	2313
44	5	15	5.62	2.94	-0.26	8.57	-3.30	-4.96	5.18	55.16	2308
92	5	15	5.62	3.03	-0.34	9.01	-3.11	-5.08	5.24	55.13	2306

TABLE B2   Raw Data in Balance Axes, Tares Not Removed
Model-Scale Units
Speed: 15.2 fps (27 knots) Turning Radius: 32 ft

Run no	Roll deg	Drift deg	Speed fps	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	TD in	SKWL in	Prop RPM
145	-35	-15	15.20	2.56	3.88	-44.71	9.89	18.30	1.06	23.74	4406
251	-35	-15	15.19	2.77	3.92	-45.94	10.25	18.62	1.02	21.19	4479
250	-35	-10	15.21	4.49	2.36	-42.70	10.05	13.78	1.89	24.12	4464
252	-35	-7	15.20	5.78	1.61	-50.84	6.40	7.80	2.88	28.62	4411
249	-35	-5	15.20	6.61	-0.03	-47.84	6.62	7.51	3.20	27.80	4410
226	-35	0	15.19	7.88	-2.58	-31.44	8.07	-0.32	4.12	30.05	4348
245	-35	0	15.17	7.90	-2.67	-33.98	7.60	1.81	3.64	26.52	4406
246	-35	5	15.18	9.29	-4.94	-20.98	7.30	-4.45	4.11	25.48	4418
247	-35	10	15.20	11.29	-10.98	-10.90	10.13	-5.95	4.65	23.77	4454
227	-35	15	15.20	13.67	-13.29	1.68	9.78	-13.69	5.59	23.65	4424
248	-35	15	15.20	13.61	-13.18	0.95	9.37	-13.98	5.08	21.57	4468
220	-20	-15	15.21	3.00	8.77	-49.41	2.51	18.65	2.75	47.71	4366
219	-20	-10	15.21	3.78	5.49	-38.81	3.30	12.38	3.12	45.93	4373
218	-20	-5	15.16	4.70	2.74	-28.54	3.81	4.92	3.53	43.04	4348
214	-20	0	15.20	5.65	0.18	-18.96	4.16	-3.56	3.97	40.26	4333
215	-20	5	15.20	6.90	-2.82	-9.24	3.84	-11.00	4.43	36.89	4326
216	-20	10	15.20	8.09	-3.46	4.59	2.95	-22.30	4.74	33.66	4344
217	-20	15	15.17	9.54	-3.49	18.04	1.81	-32.61	5.12	30.91	4325
221	-20	15	15.19	9.65	-3.49	18.46	1.90	-33.41	5.16	30.79	4350
201	-10	-15	15.20	3.50	7.72	-53.55	-5.08	16.00	3.36	48.74	4367
210	-10	-15	15.18	3.42	7.96	-52.92	-4.92	15.50	3.32	48.90	4371
200	-10	-10	15.18	3.61	4.89	-39.84	-2.91	8.47	3.46	48.81	4375
199	-10	-5	15.17	3.96	2.58	-26.72	-0.99	1.65	3.68	48.49	4366
195	-10	0	15.19	4.54	0.85	-14.99	0.24	-5.15	3.91	46.94	4362
206	-10	0	15.20	4.55	0.91	-14.69	0.42	-5.20	3.91	46.95	4360
196	-10	5	15.21	5.40	-1.17	-4.17	0.92	-12.43	4.22	44.59	4368
207	-10	5	15.20	5.41	-1.28	-3.99	1.12	-12.50	4.22	44.55	4357
197	-10	10	15.20	6.69	-2.52	8.47	1.08	-24.08	4.60	39.45	4355
208	-10	10	15.22	6.71	-2.51	8.35	1.21	-23.89	4.63	39.58	4357
198	-10	15	15.18	8.15	-1.99	23.49	0.82	-39.46	4.96	35.01	4346
202	-10	15	15.18	8.20	-2.17	23.60	1.00	-39.46	4.97	34.84	4347
209	-10	15	15.20	8.16	-2.05	23.64	1.08	-39.36	4.96	34.98	4340
118	0	-15	15.20	4.69	6.44	-45.37	-8.99	11.37	3.53	43.26	4485
117	0	-10	15.21	3.98	4.45	-35.11	-7.46	2.42	3.40	46.63	4464
115	0	-5	15.19	3.59	3.28	-23.59	-5.88	-4.75	3.29	48.01	4497
116	0	-5	15.21	3.67	2.35	-23.47	-5.87	-5.00	3.32	47.74	4441
110	0	0	15.17	3.56	0.97	-11.07	-4.35	-11.28	3.30	48.20	4428
129	0	0	15.20	3.51	0.63	-10.98	-4.28	-11.08	3.24	48.10	4378
130	0	0	15.20	3.60	1.42	-10.81	-4.30	-11.07	3.29	47.88	4441
133	0	0	15.16	3.58	1.12	-10.75	-4.28	-11.15	3.29	48.00	4418
178	0	0	15.19	3.79	1.01	-11.16	-4.36	-10.72	3.29	46.93	4394
180	0	0	15.18	3.81	1.37	-11.28	-4.41	-10.66	3.31	46.95	4411
242	0	0	15.22	3.82	1.22	-11.28	-4.16	-10.54	3.29	46.73	4424
111	0	5	15.18	3.82	-0.01	1.06	-3.06	-17.41	3.37	47.27	4424
112	0	10	15.18	4.46	-1.06	12.80	-1.46	-24.19	3.58	45.38	4394
113	0	15	15.18	5.48	-1.16	24.98	-0.10	-34.78	3.87	40.55	4366

TABLE B2 (Continued)   Raw Data in Balance Axes, Tares Not Removed
Model-Scale Units
Speed: 15.2 fps (27 knots)   Turning Radius: 32 ft

Run no	Roll deg	Drift deg	Speed fps	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	TD in	SKWL in	Prop RPM
114	0	15	15.22	5.36	0.02	24.91	-0.34	-35.09	3.80	40.62	4407
131	0	15	15.21	5.47	-0.37	25.05	-0.24	-35.14	3.82	40.09	4394
136	10	-15	15.20	5.97	4.55	-40.44	-10.24	12.89	3.94	37.87	4427
155	10	-15	15.21	6.11	4.28	-41.72	-10.80	14.10	4.01	37.66	4422
153	10	-10	15.20	5.06	1.85	-28.75	-10.53	-1.11	3.82	43.33	4415
152	10	-5	15.18	4.02	1.11	-18.69	-10.20	-10.06	3.52	47.15	4405
148	10	0	15.19	3.47	2.47	-7.92	-9.31	-15.77	3.29	48.57	4466
154	10	0	15.21	3.47	0.37	-8.19	-9.23	-15.89	3.29	48.60	4374
149	10	5	15.21	3.30	-0.11	4.49	-7.83	-22.50	3.18	48.73	4342
150	10	10	15.18	3.45	0.07	18.04	-5.90	-29.29	3.19	48.08	4350
151	10	15	15.18	3.57	0.87	31.80	-3.19	-36.64	3.20	47.50	4326
139	20	-15	15.21	7.82	-1.29	-33.36	-15.77	6.58	4.19	30.81	4397
165	20	-15	15.19	8.36	-0.83	-34.77	-13.92	9.77	4.40	30.25	4415
257	20	-15	15.18	8.30	-1.59	-33.22	-15.83	5.27	4.41	30.51	4476
164	20	-10	15.19	5.93	0.39	-25.86	-13.04	-2.41	4.04	39.10	4447
163	20	-5	15.21	4.99	-0.70	-12.87	-12.94	-10.34	3.77	43.33	4395
159	20	0	15.18	3.88	-0.99	-1.79	-12.39	-17.06	3.38	47.03	4369
255	20	0	15.21	3.98	-0.75	-2.06	-12.72	-16.98	3.42	46.74	4432
160	20	5	15.21	3.34	-0.16	7.17	-11.93	-24.56	3.06	47.83	4377
161	20	10	15.21	2.84	0.04	18.28	-10.87	-31.02	2.77	48.65	4368
162	20	15	15.21	2.48	0.70	31.69	-9.05	-37.36	2.58	49.17	4325
256	20	15	15.20	2.44	1.10	30.70	-9.55	-36.77	2.55	49.19	4411
142	35	-15	15.21	9.82	-4.41	-27.06	-18.46	-2.34	4.55	26.69	4376
190	35	-15	15.21	10.26	-3.77	-28.17	-18.93	-0.06	4.66	26.18	4389
189	35	-10	15.22	8.28	-4.91	-17.69	-19.54	-8.04	4.27	29.64	4393
188	35	-5	15.18	5.96	-2.85	-7.59	-19.10	-15.50	3.66	35.26	4389
184	35	0	15.22	5.13	-2.18	5.68	-17.81	-18.88	3.42	38.26	4388
185	35	5	15.22	4.91	-3.00	24.78	-15.91	-26.21	3.39	39.59	4396
191	35	5	15.19	4.54	-2.85	22.29	-16.11	-25.35	3.25	41.08	4330
186	35	10	15.20	2.94	-0.97	33.00	-13.93	-25.44	2.62	47.14	4385
187	35	15	15.20	1.13	-0.95	22.91	-15.81	-27.75	1.17	47.49	4362

B3

TABLE B3 Raw Data in Balance Axes, Tares Not Removed
Model-Scale Units
Speed: 5.6 fps (10 knots) Turning Radius: 15.67 ft

Run no	Roll deg	Drift deg	Speed fps	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	TD in	SKWL in	Prop RPM
414	-5	-15	5.62	1.44	2.85	-12.45	2.62	-13.26	4.82	56.90	2325
413	-5	-10	5.62	1.76	2.79	-8.22	3.05	-9.70	4.77	56.31	2324
412	-5	-5	5.61	2.08	1.35	-5.22	3.08	-6.37	4.79	55.84	2325
408	-5	0	5.62	2.39	0.77	-2.20	2.93	-5.59	4.88	55.52	2331
409	-5	5	5.61	2.71	0.09	0.72	2.68	-5.88	5.05	55.30	2327
410	-5	10	5.61	2.99	-0.18	3.52	2.43	-6.28	5.22	55.15	2324
411	-5	15	5.62	3.27	-0.27	7.11	2.46	-6.34	5.47	55.12	2325
415	-5	15	5.62	3.29	-0.35	6.85	2.47	-6.22	5.46	55.08	2325
386	0	-15	5.61	1.17	2.39	-10.37	0.23	-13.07	4.70	57.07	2331
385	0	-10	5.62	1.51	2.89	-7.35	0.05	-10.91	4.68	56.56	2343
384	0	-5	5.62	1.90	1.35	-4.54	0.14	-7.72	4.74	56.04	2325
379	0	0	5.63	2.20	0.48	-1.84	0.02	-6.67	4.85	55.75	2295
387	0	0	5.61	2.27	0.56	-1.76	0.03	-6.89	4.88	55.71	2328
381	0	5	5.61	2.65	0.06	1.42	-0.16	-7.00	5.05	55.40	2322
382	0	10	5.61	2.92	-0.09	4.22	-0.31	-7.40	5.22	55.25	2326
383	0	15	5.61	3.23	-0.18	7.55	-0.10	-7.40	5.44	55.13	2324
403	5	-15	5.60	1.01	2.36	-9.79	-2.77	-13.87	4.65	57.16	2331
402	5	-10	5.60	1.40	2.57	-6.81	-3.15	-11.90	4.68	56.72	2331
401	5	-5	5.62	1.74	1.18	-4.02	-3.11	-8.88	4.70	56.23	2329
391	5	0	5.62	2.10	0.63	-1.20	-3.20	-7.86	4.80	55.83	2331
404	5	0	5.62	2.16	0.50	-0.95	-3.12	-8.04	4.84	55.81	2333
392	5	5	5.61	2.56	0.23	2.01	-3.35	-7.94	5.00	55.45	2341
399	5	10	5.62	2.93	-0.20	5.05	-3.24	-8.49	5.23	55.25	2327
400	5	15	5.62	3.24	-0.26	8.28	-3.09	-8.68	5.45	55.14	2332

Run no	Roll deg	Drift deg	Speed fps	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	TD in	SKWL in	Prop RPM
529	-35	-15	15.15	4.12	7.02	-59.90	8.09	14.61	1.75	24.38	4494
528	-35	-10	15.18	5.72	3.39	-54.89	7.69	9.34	2.44	24.46	4482
530	-35	-10	15.15	5.73	5.13	-55.03	7.48	8.14	2.45	24.51	4485
527	-35	-5	15.14	8.82	-1.11	-63.27	5.28	1.59	4.23	27.59	4406
523	-35	0	15.15	9.50	-3.24	-46.04	4.24	-5.52	4.30	26.06	4412
532	-35	0	15.15	8.97	-2.12	-43.35	4.47	-7.20	4.10	26.30	4439
524	-35	5	15.19	10.31	-6.62	-29.46	4.41	-13.17	4.49	25.09	4426
525	-35	10	15.16	12.55	-10.75	-19.08	5.80	-16.94	5.04	23.21	4463
526	-35	15	15.17	14.08	-14.28	-6.76	5.17	-23.68	5.40	22.18	4481
531	-35	15	15.13	14.10	-14.00	-6.30	5.03	-24.01	5.44	22.33	4497
515	-20	-15	15.18	3.58	12.20	-59.96	-0.37	12.70	2.64	42.30	4402
514	-20	-10	15.16	4.60	8.00	-50.29	0.00	6.26	3.11	38.73	4411
513	-20	-5	15.20	5.57	3.86	-40.12	0.39	-1.67	3.48	35.82	4414
509	-20	0	15.21	6.79	0.22	-30.97	0.47	-9.96	3.95	33.39	4416
510	-20	5	15.16	8.09	-3.49	-19.36	-0.06	-19.88	4.40	31.23	4406
511	-20	10	15.19	9.51	-4.96	-5.34	-1.46	-32.36	4.68	28.32	4402
512	-20	15	15.14	10.60	-5.62	7.94	-3.13	-42.47	4.92	26.75	4392
516	-20	15	15.17	10.47	-5.85	7.42	-2.99	-41.76	4.93	27.16	4389
503	-10	-15	15.16	3.41	11.85	-63.86	-7.95	5.87	3.05	47.40	4438
502	-10	-10	15.18	3.04	8.98	-48.31	-5.55	-1.77	2.90	48.46	4425
501	-10	-5	15.20	3.22	5.99	-35.41	-4.24	-7.13	2.94	47.71	4418
483	-10	0	15.19	5.29	0.46	-26.39	-3.37	-12.46	4.18	44.90	4409
504	-10	0	15.15	4.49	2.39	-25.45	-3.54	-12.78	3.49	44.35	4415
498	-10	5	15.15	6.29	-2.55	-15.04	-2.95	-20.34	4.18	38.14	4400
499	-10	10	15.16	7.65	-4.40	-1.69	-2.79	-32.78	4.50	33.84	4399
484	-10	15	15.17	9.29	-4.55	14.43	-3.39	-49.99	5.21	32.26	4387
500	-10	15	15.16	9.31	-4.51	14.70	-3.43	-50.63	4.87	30.12	4396
441	0	-15	15.16	4.56	10.47	-57.96	-13.16	1.90	3.69	45.59	4445
440	0	-10	15.16	4.11	7.13	-47.13	-10.95	-5.98	3.58	47.09	4424
439	0	-5	15.19	3.92	3.80	-35.27	-9.30	-12.58	3.58	48.09	4417
429	0	0	15.15	3.98	1.28	-22.63	-8.01	-18.60	3.59	47.84	4386
431	0	0	15.18	4.05	2.93	-22.33	-8.13	-18.98	3.61	47.60	4499
432	0	0	15.17	4.02	2.50	-22.59	-7.96	-18.78	3.59	47.62	4436
433	0	0	15.17	3.94	2.33	-22.87	-8.15	-18.93	3.59	48.03	4433
434	0	0	15.17	4.05	1.88	-22.79	-8.14	-18.73	3.62	47.67	4407
436	0	5	15.15	4.40	-0.84	-9.72	-6.44	-25.38	3.72	46.52	4407
437	0	10	15.17	5.17	-2.44	1.73	-4.95	-32.39	3.91	43.35	4400
438	0	15	15.14	6.48	-3.54	16.03	-3.69	-44.63	4.29	38.06	4366
442	0	15	15.14	6.43	-3.35	15.50	-3.72	-44.10	4.28	38.22	4388
454	10	-15	15.19	6.34	6.94	-51.91	-16.23	4.80	4.32	39.13	4430
453	10	-10	15.18	4.65	4.75	-41.93	-14.98	-12.76	4.03	47.14	4433
452	10	-5	15.17	3.57	2.73	-32.76	-13.98	-19.81	3.66	49.78	4415
446	10	0	15.19	3.29	1.22	-20.33	-13.13	-26.21	3.52	50.19	4423
447	10	5	15.16	3.30	-0.65	-6.75	-11.31	-31.73	3.45	49.86	4402
455	10	5	15.18	3.34	-0.79	-7.31	-11.30	-31.33	3.48	49.83	4412
448	10	10	15.17	3.38	-1.12	6.37	-9.03	-37.69	3.41	49.41	4410

TABLE B4 (Continued)   Raw Data in Balance Axes, Tares Not Removed
                            Model-Scale Units
              Speed: 15.2 fps (27 knots)   Turning Radius: 15.67 ft

Run no	Roll deg	Drift deg	Speed fps	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	TD in	SKWL in	Prop RPM
449	10	15	15.13	3.85	-1.03	21.73	-6.01	-45.81	3.54	48.18	4408
464	20	-15	15.15	7.49	1.89	-45.54	-21.05	-2.49	4.68	35.91	4455
465	20	-15	15.17	7.51	1.81	-46.09	-21.25	-2.44	4.68	35.87	4442
463	20	-10	15.20	5.39	3.79	-38.21	-17.71	-11.10	4.15	44.17	4449
462	20	-5	15.17	3.85	1.50	-28.99	-17.91	-21.89	3.80	49.34	4434
458	20	0	15.15	3.10	0.32	-16.43	-17.20	-27.80	3.48	50.76	4438
459	20	5	15.21	2.76	-1.07	-5.70	-16.25	-32.70	3.24	51.00	4411
460	20	10	15.16	2.34	-1.30	6.63	-14.47	-39.48	2.98	51.42	4405
461	20	15	15.19	1.98	-1.13	19.52	-12.32	-44.46	2.77	51.76	4392
475	35	-15	15.14	7.44	0.67	-47.33	-26.66	-13.98	4.72	36.42	4440
474	35	-10	15.19	5.75	-1.64	-35.79	-26.31	-20.71	4.18	41.68	4433
476	35	-10	15.18	5.75	-1.74	-35.60	-26.45	-22.01	4.18	41.74	4433
473	35	-5	15.14	3.90	-2.09	-25.46	-24.36	-26.66	3.52	47.81	4449
468	35	0	15.16	3.26	-2.95	-12.51	-23.21	-29.28	3.29	49.35	4416
469	35	0	15.17	3.32	-2.48	-12.21	-23.25	-29.17	3.31	49.21	4447
470	35	5	15.17	3.00	-3.07	5.00	-20.98	-33.09	3.26	50.16	4410
471	35	10	15.16	1.72	-3.12	17.47	-18.09	-32.85	2.79	52.48	4404
472	35	15	15.17	0.47	-2.42	26.50	-15.61	-30.23	2.15	54.01	4410

TABLE B5   Raw Data in Balance Axes, Tares Not Removed
Model-Scale Units
Speed: 5.6 fps (10 knots)   Turning Radius: 15.67 ft
Drift Angle: 0 degrees
Rudder Deflection Tests

Run no	Roll deg	Ruddr deg	Speed fps	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	TD in	SKWL in	Prop RPM
322	-20	-30	5.63	3.35	-2.02	-8.34	12.43	7.80	4.92	54.16	2316
321	-20	-20	5.63	3.33	-1.07	-7.22	11.68	5.84	4.89	54.13	2320
320	-20	0	5.63	3.35	-0.67	-3.39	9.63	-0.45	4.85	53.97	2313
323	-20	0	5.62	3.29	-0.52	-3.38	9.63	-0.45	4.83	54.08	2326
319	-20	20	5.63	3.32	-1.47	0.13	7.74	-6.12	4.80	53.92	2313
318	-20	30	5.62	3.28	-2.10	-0.73	7.99	-4.82	4.77	53.94	2317
306	0	-30	5.62	2.49	-1.67	-7.12	2.38	6.26	4.87	55.35	2316
305	0	-20	5.61	2.36	-0.27	-5.42	1.67	3.50	4.82	55.46	2324
301	0	0	5.62	2.18	0.65	-0.92	-0.01	-3.81	4.76	55.64	2331
302	0	0	5.62	2.22	0.50	-0.94	-0.02	-3.82	4.77	55.60	2317
303	0	20	5.62	2.41	-0.62	3.04	-1.59	-10.43	4.87	55.47	2313
304	0	30	5.63	2.30	-1.87	2.74	-1.36	-9.95	4.82	55.55	2314
309	20	-30	5.63	2.91	-2.22	-4.35	-7.36	3.47	4.73	54.51	2320
310	20	-20	5.63	3.01	-1.52	-2.50	-8.23	0.56	4.81	54.49	2321
311	20	0	5.63	2.63	-0.49	1.78	-10.44	-6.77	4.71	54.90	2317
312	20	20	5.62	2.57	-1.35	5.29	-12.18	-12.71	4.75	55.04	2315
313	20	30	5.62	1.92	-1.11	2.64	-10.47	-8.66	4.39	55.47	2320
314	20	30	5.62	1.79	-1.03	2.70	-10.43	-8.76	4.34	55.58	2316

TABLE B6   Raw Data in Balance Axes, Tares Not Removed
Model-Scale Units
Speed: 15.2 fps (27 knots) Turning Radius: 32 ft
Drift Angle: 0 degrees
Rudder Deflection Tests

Run no	Roll deg	Ruddr deg	Speed fps	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	TD in	SKWL in	Prop RPM
287	-20	-30	15.20	6.34	-6.33	-42.63	17.45	32.82	3.80	34.35	4361
286	-20	-20	15.20	6.20	-2.97	-37.82	14.29	25.05	3.72	34.45	4377
283	-20	0	15.21	5.61	0.37	-19.91	4.43	-2.69	3.48	35.58	4394
288	-20	10	15.20	5.40	0.33	-9.26	-1.11	-19.01	3.36	35.68	4357
284	-20	20	15.21	4.39	-1.22	-13.22	-1.64	-12.47	3.21	41.84	4392
285	-20	30	15.20	-1.47	-6.44	-14.96	3.91	-5.48	1.77	56.61	4438
265	0	-30	15.20	3.74	-4.55	-35.01	7.37	29.97	3.19	46.54	4439
262	0	-20	15.17	3.79	-1.56	-30.29	4.84	21.71	3.23	46.54	4433
264	0	-20	15.20	3.71	-1.29	-29.12	4.32	19.70	3.22	46.87	4424
261	0	0	15.18	3.83	0.99	-11.45	-4.16	-10.37	3.30	46.80	4431
263	0	0	15.18	3.84	1.18	-10.26	-4.63	-12.09	3.31	46.77	4437
269	0	10	15.19	4.16	-0.13	-1.62	-9.27	-27.13	3.45	46.08	4416
266	0	20	15.22	2.91	-1.01	-5.79	-9.77	-23.59	3.15	50.02	4420
268	0	30	15.19	-2.43	-5.19	-14.37	-3.81	-33.94	2.08	57.90	4421
279	20	-30	15.20	3.18	-4.37	-27.53	-0.72	23.25	2.78	46.80	4407
278	20	-20	15.19	3.34	-1.66	-20.73	-3.82	12.48	2.97	47.25	4424
274	20	0	15.18	4.14	-1.17	-1.47	-12.73	-17.35	3.49	46.40	4442
273	20	10	15.21	4.55	-2.69	9.58	-17.96	-34.42	3.76	46.06	4434
276	20	20	15.20	4.76	-5.15	17.49	-22.11	-47.58	3.94	46.08	4422
277	20	30	15.20	-1.92	-6.83	-18.43	-14.18	-46.08	1.92	57.32	4417

TABLE B7   Raw Data in Balance Coordinate System
Zero Speed Runs
Model-Scale Units

Run	Radius feet	Roll deg	Drift deg	Trim deg	X lb	Y lb	K lb-ft	N lb-ft	TD inch	SKWL inch
30	32.00	0.00	0.00	0.16	-0.31	0.76	0.59	-0.25	3.29	56.46
32	32.00	0.00	0.00	0.21	0.35	-0.31	-0.25	0.06	3.42	56.59
39	32.00	5.00	0.00	0.24	0.00	-0.01	-3.06	0.00	3.40	56.51
49	32.00	-5.00	0.00	0.31	0.01	-0.02	3.43	0.00	3.44	56.46
77	32.00	-5.00	-10.00	0.30	-0.05	0.07	3.65	-0.06	3.31	56.27
90	32.00	5.00	0.00	0.22	-0.17	0.09	-2.85	-0.05	3.30	56.38
98	32.00	0.00	0.00	0.20	-0.08	-0.10	0.23	-0.08	3.35	56.49
108	32.00	0.00	0.00	0.22	-0.15	0.14	0.49	-0.08	3.34	56.44
128	32.00	0.00	0.00	0.18	-0.15	0.09	0.45	-0.07	3.31	56.46
138	32.00	20.00	-15.00	0.20	-0.23	0.08	-9.69	-0.11	2.97	55.87
141	32.00	35.00	-15.00	0.20	-0.29	0.01	-13.10	-0.10	2.39	54.91
144	32.00	-35.00	-15.00	0.57	0.00	-0.14	14.95	-0.13	2.45	54.41
147	32.00	10.00	0.00	0.28	-0.17	0.05	-5.75	-0.05	3.31	56.30
158	32.00	20.00	0.00	0.21	-0.25	0.04	-9.32	-0.03	3.05	55.98
177	32.00	0.00	0.00	0.23	-0.11	0.11	0.42	-0.08	3.33	56.41
183	32.00	35.00	0.00	0.07	-0.14	-0.23	-14.67	-0.09	2.33	55.01
194	32.00	-10.00	0.00	0.50	-0.08	-0.12	6.31	-0.06	3.85	56.82
205	32.00	-10.00	0.00	0.50	-0.07	0.05	6.58	-0.10	3.85	56.83
213	32.00	-20.00	0.00	0.56	0.05	-0.13	10.42	-0.08	3.57	56.27
225	32.00	-35.00	0.00	0.65	0.12	-0.15	14.89	-0.13	2.92	55.07
244	32.00	-35.00	0.00	0.54	0.16	-0.11	14.98	-0.08	2.36	54.32
254	32.00	20.00	0.00	0.24	-0.23	0.02	-9.77	-0.06	3.02	55.89
260	32.00	0.00	0.00	0.21	-0.17	0.06	0.66	-0.04	3.33	56.44
272	32.00	20.00	0.00	0.23	-0.24	0.07	-9.73	-0.06	3.06	55.96
299	32.00	0.00	0.00	0.23	-0.09	0.04	0.66	-0.06	3.40	56.53
308	32.00	20.00	0.00	0.20	-0.18	0.05	-9.73	-0.07	3.09	56.06
317	32.00	-20.00	0.00	0.47	0.04	0.05	10.59	-0.09	3.10	55.63
380	15.67	0.00	5.00	0.18	0.01	0.53	0.95	0.02	3.63	56.98
390	15.67	5.00	0.00	0.17	-0.02	0.52	-2.36	-0.01	3.60	56.96
407	15.67	-5.00	0.00	0.29	0.05	0.57	4.29	-0.02	3.66	56.86
445	15.67	10.00	0.00	0.15	-0.07	1.08	-4.83	0.14	3.45	56.75
457	15.67	20.00	0.00	0.09	-0.23	0.40	-9.39	-0.01	3.24	56.49
482	15.67	-10.00	0.00	0.41	-0.03	0.65	6.94	-0.01	3.85	56.97
497	15.67	-10.00	5.00	0.42	0.00	0.36	6.85	-0.06	3.56	56.49
505	15.67	-10.00	0.00	0.42	-0.07	0.42	6.98	-0.01	3.57	56.50
508	15.67	-20.00	0.00	0.52	-0.02	0.44	10.85	-0.04	3.33	55.94
522	15.67	-35.00	0.00	0.63	0.04	0.42	15.23	-0.10	2.81	54.91

TABLE B8 Wetted Lengths and Areas determined from Underwater Photos
SPEED: 10 knots   R/L: 6.74

Run no	Roll deg	Drift deg	Keel in	Stbd Chine in	Stbd Trnsm *	Port Chine in	Port Trnsm *	Stbd sq ft	Port sq ft	Total sq ft
83	-5	-15	56	0	0.5	35	1.0	0.84	2.80	3.64
71	-5	-10	56	13	1.0	35	1.0	2.12	2.80	4.92
89	-5	-10	56	43	1.0	34	1.0	2.99	2.78	5.77
70	-5	-5	56	15	1.0	35	1.0	2.20	2.80	5.00
88	-5	-5	56	15	1.0	35	1.0	2.20	2.80	5.00
50	-5	0	56	45	1.0	45	1.0	3.03	3.03	6.07
65	-5	0	56	18	1.0	35	1.0	2.31	2.80	5.11
81	-5	0	56	16	1.0	35	1.0	2.23	2.80	5.04
51	-5	5	56	16	1.0	42	1.0	2.23	2.97	5.20
66	-5	5	56	15	1.0	41	1.0	2.20	2.95	5.14
87	-5	5	56	15	1.0	44	1.0	2.20	3.01	5.21
52	-5	10	56	18	1.0	41	1.0	2.31	2.95	5.25
68	-5	10	56	16	1.0	39	1.0	2.23	2.90	5.14
78	-5	10	56	17	1.0	39	1.0	2.27	2.90	5.18
79	-5	10	56	17	1.0	40	1.0	2.27	2.93	5.20
53	-5	15	56	19	1.0	45	1.0	2.34	3.03	5.38
69	-5	15	56	19	1.0	42	1.0	2.34	2.97	5.31
80	-5	15	56	20	1.0	41	1.0	2.38	2.95	5.32
105	0	-15	57	48	1.0	31	1.0	3.12	2.73	5.85
104	0	-10	56	49	1.0	30	1.0	3.11	2.68	5.78
103	0	-5	56	46	1.0	28	1.0	3.05	2.62	5.68
99	0	0	56	25	1.0	28	1.0	2.53	2.62	5.16
100	0	5	56	25	1.0	45	1.0	2.53	3.03	5.57
101	0	10	56	25	1.0	45	1.0	2.53	3.03	5.57
102	0	15	56	26	1.0	47	1.0	2.56	3.07	5.64
47	5	-15	57	50	1.0	23	1.0	3.15	2.51	5.65
93	5	-15	57	52	1.0	24	1.0	3.17	2.54	5.71
46	5	-10	57	49	1.0	22	1.0	3.13	2.48	5.61
94	5	-10	57	49	1.0	22	1.0	3.13	2.48	5.61
97	5	-5	56	50	1.0	19	1.0	3.12	2.34	5.46
91	5	0	56	48	1.0	19	1.0	3.09	2.34	5.43
96	5	5	56	49	1.0	18	1.0	3.11	2.31	5.41
95	5	10	56	33	1.0	20	1.0	2.75	2.38	5.13
92	5	15	56	34	1.0	44	1.0	2.78	3.01	5.79

*Wetted transom lengths are given as fractions of the maximum

TABLE B9 Wetted Lengths and Areas determined from Underwater Photos
SPEED: 27 knots R/L: 6.74

Run no	Roll deg	Drift deg	Keel in	Stbd Chine in	Stbd Trnsm *	Port Chine in	Port Trnsm *	Stbd sq ft	Port sq ft	Total sq ft
145	-35	-15	34	0	0.4	39	1.0	0.40	2.26	2.66
251	-35	-15	34	0	0.4	39	1.0	0.40	2.26	2.66
250	-35	-10	31	0	0.4	37	1.0	0.37	2.11	2.48
252	-35	-7	36	0	0.8	38	1.0	0.86	2.29	3.14
249	-35	-5	35	0	0.8	39	1.0	0.83	2.29	3.12
226	-35	0	33	0	0.6	37	1.0	0.59	2.17	2.76
245	-35	0	33	0	0.6	37	1.0	0.59	2.17	2.76
246	-35	5	31	0	0.7	36	1.0	0.64	2.08	2.72
247	-35	10	29	0	0.5	34	1.0	0.43	1.95	2.38
227	-35	15	27	0	0.4	32	1.0	0.32	1.83	2.15
248	-35	15	27	0	0.2	32	1.0	0.16	1.83	1.99
220	-20	-15	46	0	0.9	36	1.0	1.23	2.53	3.76
219	-20	-10	46	0	0.9	35	1.0	1.23	2.50	3.74
218	-20	-5	41	5	1.0	35	1.0	1.39	2.35	3.74
215	-20	5	37	5	1.0	32	1.0	1.26	2.14	3.40
216	-20	10	35	6	1.0	33	1.0	1.23	2.11	3.34
217	-20	15	35	0	0.5	31	1.0	0.52	2.05	2.57
221	-20	15	34	10	0.0	31	1.0	0.00	2.02	2.02
201	-10	-15	47	15	1.0	27	1.0	1.91	2.31	4.22
200	-10	-10	48	16	1.0	26	1.0	1.98	2.31	4.29
199	-10	-5	50	14	1.0	26	1.0	1.97	2.37	4.34
195	-10	0	48	19	1.0	12	1.0	2.08	1.83	3.92
196	-10	5	45	15	1.0	29	1.0	1.85	2.30	4.15
197	-10	10	40	14	1.0	28	1.0	1.66	2.11	3.77
198	-10	15	36	14	1.0	28	1.0	1.53	1.99	3.52
118	0	-15	46	23	1.0	22	1.0	2.15	2.12	4.28
117	0	-10	48	25	1.0	24	1.0	2.28	2.25	4.53
115	0	-5	49	25	1.0	27	1.0	2.31	2.37	4.68
116	0	-5	50	25	1.0	25	1.0	2.34	2.34	4.68
109	0	0	50	25	1.0	26	1.0	2.34	2.37	4.71
110	0	0	51	25	1.0	23	1.0	2.37	2.32	4.69
129	0	0	50	26	1.0	23	1.0	2.37	2.28	4.66
130	0	0	51	25	1.0	25	1.0	2.37	2.37	4.75
133	0	0	51	25	1.0	23	1.0	2.37	2.32	4.69
178	0	0	49	25	1.0	24	1.0	2.31	2.28	4.59
242	0	0	50	26	1.0	25	1.0	2.37	2.34	4.71
111	0	5	50	23	1.0	24	1.0	2.28	2.31	4.60
112	0	10	49	23	1.0	25	1.0	2.25	2.31	4.56
113	0	15	44	23	1.0	22	1.0	2.09	2.06	4.15
114	0	15	45	22	1.0	25	1.0	2.09	2.18	4.27
131	0	15	45	23	1.0	23	1.0	2.12	2.12	4.24
136	10	-15	40	6	1.0	32	1.0	1.39	2.23	3.62
155	10	-15	40	30	1.0	14	1.0	2.17	1.66	3.83
153	10	-10	45	23	1.0	15	1.0	2.12	1.85	3.97
152	10	-5	50	31	1.0	14	1.0	2.51	1.97	4.48
148	10	0	50	34	1.0	16	1.0	2.60	2.04	4.64
154	10	0	51	34	1.0	17	1.0	2.63	2.11	4.74

TABLE B9 (Continued)   Wetted Lengths and Areas determined from
Underwater Photos
SPEED: 27 knots   R/L: 6.74

Run no	Roll deg	Drift deg	Keel in	Stbd Chine in	Stbd Trnsm *	Port Chine in	Port Trnsm *	Stbd sq ft	Port sq ft	Total sq ft
149	10	5	50	26	1.0	16	1.0	2.37	2.04	4.42
150	10	10	49	27	1.0	18	1.0	2.37	2.08	4.45
151	10	15	49	26	1.0	18	1.0	2.34	2.08	4.42
165	20	-15	34	32	1.0	0	0.4	2.05	0.40	2.45
257	20	-15	34	32	1.0	0	0.4	2.05	0.40	2.45
164	20	-10	42	36	1.0	0	0.8	2.41	1.00	3.41
163	20	-5	47	39	1.0	0	0.9	2.64	1.26	3.90
159	20	0	48	38	1.0	10	1.0	2.64	1.76	4.41
255	20	0	49	38	1.0	9	1.0	2.67	1.76	4.43
160	20	5	49	38	1.0	9	1.0	2.67	1.76	4.43
161	20	10	50	29	1.0	10	1.0	2.46	1.83	4.29
162	20	15	49	30	1.0	6	1.0	2.46	1.66	4.12
256	20	15	51	30	1.0	7	1.0	2.52	1.76	4.28
142	35	-15	31	35	1.0	0	0.4	2.05	0.37	2.41
190	35	-15	31	36	1.0	0	0.3	2.08	0.28	2.35
189	35	-10	35	38	1.0	0	0.2	2.26	0.21	2.47
188	35	-5	40	40	1.0	0	0.4	2.46	0.48	2.94
184	35	0	41	42	1.0	0	0.6	2.55	0.73	3.28
185	35	5	44	43	1.0	0	0.8	2.66	1.05	3.71
191	35	5	45	43	1.0	0	0.6	2.69	0.80	3.49
186	35	10	47	45	1.0	0	0.6	2.80	0.84	3.64
187	35	15	46	44	1.0	0	0.5	2.74	0.69	3.43

*Wetted transom lengths are given as fractions of the maximum

TABLE B10 Wetted Lengths and Areas determined from Underwater Photos
SPEED: 10 knots   R/L: 3.30

Run no	Roll deg	Drift deg	Keel in	Stbd Chine in	Stbd Trnsm *	Port Chine in	Port Trnsm *	Stbd sq ft	Port sq ft	Total sq ft
414	-5	-15	57	55	1.0	38	1.0	3.21	2.91	6.11
413	-5	-10	56	45	1.0	37	1.0	3.03	2.85	5.89
412	-5	-5	56	45	0.9	37	1.0	2.73	2.85	5.58
408	-5	0	56	45	1.0	42	1.0	3.03	2.97	6.00
409	-5	5	56	45	0.9	47	0.9	2.73	2.77	5.50
410	-5	10	55	16	0.9	45	1.0	1.98	3.01	4.99
411	-5	15	55	17	0.9	47	1.0	2.02	3.05	5.06
415	-5	15	55	17	0.9	46	1.0	2.02	3.03	5.04
386	0	-15	55	45	1.0	32	1.0	3.01	2.70	5.70
385	0	-10	57	45	1.0	32	1.0	3.06	2.76	5.82
384	0	-5	56	46	1.0	32	1.0	3.05	2.73	5.78
379	0	0	56	45	1.0	31	1.0	3.03	2.70	5.74
387	0	0	56	45	1.0	31	1.0	3.03	2.70	5.74
381	0	5	56	44	1.0	32	1.0	3.01	2.73	5.74
382	0	10	55	25	1.0	45	1.0	2.50	3.01	5.51
383	0	15	55	26	1.0	46	1.0	2.53	3.03	5.56
403	5	-15	56	11	1.0	27	1.0	2.04	2.59	4.64
402	5	-10	57	45	1.0	25	1.0	3.06	2.57	5.63
401	5	-5	57	49	1.0	24	1.0	3.13	2.54	5.67
391	5	0	56	47	1.0	25	1.0	3.07	2.53	5.61
404	5	0	56	46	1.0	22	1.0	3.05	2.44	5.50
392	5	5	56	46	1.0	25	1.0	3.05	2.53	5.59
399	5	10	55	46	1.0	28	1.0	3.03	2.59	5.62
400	5	15	55	32	1.0	43	1.0	2.70	2.96	5.66

*Wetted transom lengths are given as fractions of maximum

TABLE B11 Wetted Lengths and Areas determined from Underwater Photos
SPEED: 27 knots R/L: 3.30

| | | | | | <------WETTED LENGTHS------> | | | <---WETTED AREAS--> | | |
Run no	Roll deg	Drift deg	Keel in	Stbd Chine in	Stbd Trnsm *	Port Chine in	Port Trnsm *	Stbd sq ft	Port sq ft	Total sq ft
529	-35	-15	31	0	0.5	38	1.0	0.46	2.14	2.60
528	-35	-10	31	0	0.5	37	1.0	0.46	2.11	2.57
530	-35	-10	30	0	0.5	37	1.0	0.44	2.08	2.52
527	-35	-5	33	0	0.6	37	1.0	0.59	2.17	2.76
523	-35	0	31	0	0.7	36	1.0	0.64	2.08	2.72
532	-35	0	31	0	0.6	35	1.0	0.55	2.05	2.60
524	-35	5	30	0	0.6	35	1.0	0.53	2.02	2.55
525	-35	10	27	0	0.5	33	1.0	0.40	1.86	2.26
526	-35	15	26	0	0.4	32	1.0	0.31	1.80	2.11
531	-35	15	26	0	0.4	32	1.0	0.31	1.80	2.11
515	-20	-15	45	0	0.9	27	1.0	1.21	2.24	3.45
514	-20	-10	42	5	1.0	28	1.0	1.42	2.18	3.59
513	-20	-5	40	5	1.0	27	1.0	1.35	2.08	3.44
509	-20	0	37	9	1.0	31	1.0	1.39	2.11	3.50
510	-20	5	35	7	1.0	32	1.0	1.27	2.08	3.34
511	-20	10	32	6	1.0	30	1.0	1.14	1.92	3.06
512	-20	15	30	0	0.8	29	1.0	0.71	1.83	2.54
516	-20	15	31	2	1.0	29	1.0	0.98	1.86	2.84
503	-10	-15	49	16	1.0	20	1.0	2.01	2.15	4.16
502	-10	-10	49	13	1.0	18	1.0	1.90	2.08	3.98
501	-10	-5	48	13	1.0	25	1.0	1.87	2.28	4.15
483	-10	0	45	16	1.0	30	1.0	1.89	2.33	4.22
504	-10	0	46	14	1.0	24	1.0	1.84	2.18	4.03
498	-10	5	41	15	1.0	28	1.0	1.72	2.15	3.87
499	-10	10	38	15	1.0	27	1.0	1.63	2.02	3.65
484	-10	15	34	15	1.0	24	1.0	1.50	1.80	3.30
500	-10	15	34	13	1.0	27	1.0	1.43	1.89	3.32
441	0	-15	47	24	1.0	23	1.0	2.22	2.19	4.40
440	0	-10	49	23	1.0	23	1.0	2.25	2.25	4.50
439	0	-5	49	26	1.0	25	1.0	2.34	2.31	4.65
429	0	0	49	26	1.0	26	1.0	2.34	2.34	4.68
430	0	0	48	25	1.0	25	1.0	2.28	2.28	4.56
431	0	0	48	25	1.0	25	1.0	2.28	2.28	4.56
436	0	5	48	30	1.0	30	1.0	2.42	2.42	4.85
437	0	10	45	22	1.0	24	1.0	2.09	2.15	4.24
438	0	15	41	22	1.0	23	1.0	1.96	1.99	3.95
442	0	15	40	22	1.0	23	1.0	1.93	1.96	3.89
454	10	-15	43	30	1.0	11	1.0	2.27	1.64	3.91
453	10	-10	48	31	1.0	12	1.0	2.45	1.83	4.28
452	10	-5	50	33	1.0	15	1.0	2.57	2.01	4.58
446	10	0	51	33	1.0	20	1.0	2.60	2.21	4.81
447	10	5	51	32	1.0	19	1.0	2.57	2.18	4.75
455	10	5	50	33	1.0	19	1.0	2.57	2.15	4.72
448	10	10	50	28	1.0	17	1.0	2.43	2.08	4.51
449	10	15	48	27	1.0	17	1.0	2.34	2.02	4.36
464	20	-15	37	35	1.0	0	0.4	2.23	0.44	2.67
465	20	-15	37	34	1.0	0	0.4	2.20	0.44	2.64

TABLE B11 (Continued)   Wetted Lengths and Areas determined from
Underwater Photos
SPEED: 27 knots   R/L: 3.30

				<-------WETTED LENGTHS------>				<---WETTED AREAS-->		
Run	Roll	Drift	Keel	Stbd	Stbd	Port	Port	Stbd	Port	Total
no	deg	deg	in	Chine	Trnsm	Chine	Trnsm	sq ft	sq ft	sq ft
				in	*	in	*			
463	20	-10	45	36	1.0	0	0.5	2.50	0.67	3.17
462	20	-5	50	40	1.0	0	0.7	2.75	1.04	3.80
458	20	0	51	38	1.0	0	0.9	2.73	1.37	4.10
459	20	5	50	37	1.0	0	0.6	2.68	0.90	3.57
460	20	10	51	38	1.0	0	0.8	2.73	1.22	3.95
461	20	15	51	40	1.0	0	0.6	2.78	0.91	3.70
475	35	-15	39	41	1.0	0	0.4	2.46	0.46	2.93
474	35	-10	39	42	1.0	0	0.1	2.49	0.12	2.61
476	35	-10	44	42	1.0	0	0.2	2.63	0.26	2.90
473	35	-5	48	43	1.0	0	0.1	2.77	0.14	2.91
468	35	0	49	46	1.0	0	0.2	2.87	0.29	3.16
469	35	0	48	45	1.0	0	0.2	2.82	0.29	3.11
470	35	5	49	46	1.0	0	0.6	2.87	0.88	3.75
471	35	10	51	43	1.0	0	0.5	2.85	0.76	3.62
472	35	15	52	45	1.0	0	0.4	2.93	0.62	3.55

*Wetted transom lengths are given as fractions of maximum

TABLE B12 Wetted Lengths and Areas determined from Underwater Photos
SPEED: 10 knots   R/L: 6.74   Drift Angle: 0 deg
Rudder Deflection Tests

Run no	Roll deg	Drift deg	Keel in	Stbd Chine in	Stbd Trnsm *	Port Chine in	Port Trnsm *	Stbd sq ft	Port sq ft	Total sq ft
322	-20	-30	55	45	0.5	49	1.0	1.50	3.08	4.59
321	-20	-20	55	45	0.5	49	1.0	1.50	3.08	4.59
320	-20	0	55	45	0.5	49	1.0	1.50	3.08	4.59
323	-20	0	55	45	0.5	49	1.0	1.50	3.08	4.59
319	-20	20	55	45	0.5	49	1.0	1.50	3.08	4.59
318	-20	30	55	45	0.5	49	1.0	1.50	3.08	4.59
306	0	-30	56	45	1.0	40	1.0	3.03	2.93	5.96
305	0	-20	56	45	1.0	40	1.0	3.03	2.93	5.96
300	0	0	56	45	1.0	40	1.0	3.03	2.93	5.96
301	0	0	56	45	1.0	42	1.0	3.03	2.97	6.00
302	0	0	56	46	1.0	44	1.0	3.05	3.01	6.07
303	0	20	56	46	1.0	46	1.0	3.05	3.05	6.11
304	0	30	56	46	1.0	43	1.0	3.05	2.99	6.05
309	20	-30	55	49	1.0	43	0.7	3.08	2.07	5.16
310	20	-20	55	49	1.0	43	0.6	3.08	1.78	4.86
311	20	0	55	51	1.0	43	0.7	3.12	2.07	5.19
312	20	20	55	51	1.0	43	0.8	3.12	2.37	5.49
313	20	30	56	52	1.0	40	0.8	3.15	2.34	5.50
314	20	30	56	52	1.0	42	0.8	3.15	2.38	5.53

*Wetted transom lengths are given as fractions of the maximum

TABLE B13 Wetted Lengths and Areas determined from Underwater Photos
        SPEED: 27 knots R/L: 6.74 Drift Angle: 0 deg
        Rudder Deflection Tests

Run no	Roll deg	Rudder deg	Keel in	Stbd Chine in	Stbd Trnsm *	Port Chine in	Port Trnsm *	Stbd sq ft	Port sq ft	Total sq ft
287	-20	-30	40	12	1.0	32	1.0	1.58	2.23	3.82
286	-20	-20	40	10	1.0	33	1.0	1.52	2.26	3.78
283	-20	0	41	4	1.0	34	1.0	1.35	2.32	3.67
288	-20	10	42	5	1.0	32	1.0	1.42	2.29	3.71
284	-20	20	45	4	1.0	35	1.0	1.47	2.47	3.95
285	-20	30	55	51	0.3	55	1.0	0.94	3.18	4.11
265	0	-30	49	25	1.0	24	1.0	2.31	2.28	4.59
262	0	-20	48	25	1.0	24	1.0	2.28	2.25	4.53
264	0	-20	49	26	1.0	26	1.0	2.34	2.34	4.68
261	0	0	50	25	1.0	24	1.0	2.34	2.31	4.66
263	0	0	50	26	1.0	25	1.0	2.37	2.34	4.71
269	0	10	48	25	1.0	25	1.0	2.28	2.28	4.56
266	0	20	51	29	1.0	30	1.0	2.49	2.52	5.01
268	0	30	59	59	1.0	59	1.0	3.25	3.25	6.49
279	20	-30	46	36	1.0	0	0.8	2.53	1.10	3.63
278	20	-20	47	41	1.0	0	0.8	2.69	1.12	3.81
274	20	0	47	38	1.0	9	1.0	2.61	1.70	4.31
273	20	10	48	37	1.0	13	1.0	2.62	1.87	4.48
276	20	20	51	38	1.0	15	1.0	2.73	2.04	4.77
277	20	30	45	55	1.0	45	0.5	3.04	1.37	4.41

*Wetted transom lengths are given as fractions of the maximum

[BLANK]

APPENDIX C

TEST DATA IN WATERPLANE AXES CENTERED AT CG.

Data in model-scale units. Tares have not been removed.

[BLANK]

TABLE C1   Test Data in Waterplane Axes
Model-Scale Units
Speed: 5.6 fps (10 knots) R/L: 6.74

Run no	Roll deg	Drift deg	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	Prop RPM
83	-5	-15	2.05	0.45	-9.04	3.93	-7.50	2314.
89	-5	-10	2.04	0.97	-5.22	3.62	-4.31	2306.
88	-5	-5	2.15	0.65	-2.29	2.96	-2.59	2314.
50	-5	0	2.23	0.25	0.48	1.87	-2.41	2308.
81	-5	0	2.33	0.27	0.59	2.15	-2.62	2309.
51	-5	5	2.50	-0.10	3.24	1.03	-2.94	2307.
87	-5	5	2.43	0.44	3.20	1.13	-3.07	2313.
52	-5	10	2.70	-0.07	6.04	0.27	-2.95	2303.
78	-5	10	2.72	-0.23	6.17	0.48	-3.06	2261.
79	-5	10	2.71	0.03	6.22	0.45	-3.11	2298.
53	-5	15	2.88	0.02	9.28	-0.45	-2.52	2299.
80	-5	15	2.93	0.23	9.49	-0.41	-2.76	2306.
38	0	-15	1.68	1.11	-8.35	1.41	-8.56	2312.
105	0	-15	1.73	0.96	-8.61	1.79	-9.23	2321.
37	0	-10	1.88	0.83	-4.80	0.99	-5.43	2296.
104	0	-10	1.93	0.73	-4.76	1.48	-5.84	2312.
36	0	-5	2.02	0.44	-2.08	0.37	-3.68	2291.
103	0	-5	2.02	0.42	-1.74	0.89	-3.88	2311.
99	0	0	2.15	0.35	1.11	0.11	-3.56	2316.
33	0	5	2.30	0.56	4.06	-1.20	-4.06	2299.
100	0	5	2.40	0.24	3.92	-0.78	-4.12	2317.
34	0	10	2.64	0.24	6.45	-1.95	-4.00	2292.
101	0	10	2.77	-0.02	6.84	-1.47	-4.24	2315.
35	0	15	2.82	0.39	9.52	-2.47	-3.37	2289.
102	0	15	2.84	0.38	10.07	-2.08	-3.57	2306.
47	5	-15	1.48	0.96	-7.32	-0.35	-9.46	2311.
93	5	-15	1.55	0.89	-7.69	-0.22	-10.42	2309.
46	5	-10	1.74	0.63	-3.93	-0.82	-6.55	2312.
94	5	-10	1.79	0.62	-3.96	-0.64	-6.88	2309.
45	5	-5	1.99	0.22	-1.11	-1.44	-4.87	2322.
97	5	-5	2.03	0.20	-0.96	-1.23	-4.96	2314.
40	5	0	2.14	0.15	1.86	-2.18	-4.59	2315.
91	5	0	2.15	0.21	2.01	-2.04	-4.70	2313.
41	5	5	2.40	0.14	4.67	-3.01	-5.08	2320.
96	5	5	2.51	-0.05	4.85	-2.84	-5.20	2313.
43	5	10	2.68	0.13	7.27	-3.80	-5.19	2315.
95	5	10	2.78	-0.05	7.68	-3.58	-5.33	2313.
44	5	15	2.94	0.27	10.55	-4.17	-4.79	2308.
92	5	15	3.03	0.19	10.99	-4.08	-4.90	2306.

TABLE C2   Test Data in Waterplane Axes
Model-Scale Units
Speed: 15.2 fps (27 knots)   R/L: 6.74

Run no	Roll deg	Drift deg	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	Prop RPM
145	-35	-15	2.56	0.12	-29.71	11.42	18.43	4406.
251	-35	-15	2.77	0.17	-30.96	12.01	18.69	4479.
250	-35	-10	4.49	-0.13	-27.62	11.12	13.58	4464.
252	-35	-7	5.78	-0.12	-35.78	8.94	7.09	4411.
249	-35	-5	6.61	-1.25	-32.79	8.58	6.85	4410.
226	-35	0	7.88	-2.53	-16.47	6.93	-0.44	4348.
245	-35	0	7.90	-2.62	-19.05	6.93	1.59	4406.
246	-35	5	9.29	-3.62	-6.15	4.19	-4.14	4418.
247	-35	10	11.29	-8.39	3.79	5.19	-4.59	4454.
227	-35	15	13.67	-9.43	16.13	2.63	-11.35	4424.
248	-35	15	13.61	-9.32	15.40	2.35	-11.72	4468.
220	-20	-15	3.00	5.01	-34.39	8.95	18.26	4366.
219	-20	-10	3.78	3.00	-23.73	7.37	12.12	4373.
218	-20	-5	4.70	1.53	-13.57	5.60	4.81	4348.
214	-20	0	5.65	0.23	-3.97	3.84	-3.44	4333.
215	-20	5	6.90	-1.50	5.63	1.41	-10.52	4326.
216	-20	10	8.09	-0.87	19.28	-2.44	-21.33	4344.
217	-20	15	9.54	0.35	32.44	-6.40	-31.00	4325.
221	-20	15	9.65	0.36	32.89	-6.40	-31.76	4350.
201	-10	-15	3.50	3.96	-38.55	4.88	15.67	4367.
210	-10	-15	3.42	4.21	-37.96	4.90	15.18	4371.
200	-10	-10	3.61	2.41	-24.82	3.87	8.34	4375.
199	-10	-5	3.96	1.37	-11.73	2.76	1.70	4366.
195	-10	0	4.54	0.90	-0.02	1.29	-4.93	4362.
206	-10	0	4.55	0.96	0.30	1.40	-4.97	4360.
196	-10	5	5.40	0.15	10.72	-0.51	-11.96	4368.
207	-10	5	5.41	0.04	10.88	-0.35	-12.02	4357.
197	-10	10	6.69	0.07	23.16	-3.19	-23.18	4355.
208	-10	10	6.71	0.0	23.08	-3.04	-23.00	4357.
198	-10	15	8.15	1.86	37.91	-6.79	-37.90	4346.
202	-10	15	8.20	1.68	38.02	-6.63	-37.88	4347.
209	-10	15	8.16	1.81	38.09	-6.56	-37.79	4340.
118	0	-15	4.69	2.68	-30.37	1.52	11.15	4485.
117	0	-10	3.98	1.96	-20.03	0.62	2.45	4464.
115	0	-5	3.59	2.06	-8.56	-0.51	-4.56	4497.
116	0	-5	3.67	1.13	-8.40	-0.52	-4.81	4441.
110	0	0	3.56	1.02	3.86	-1.90	-10.95	4428.
129	0	0	3.51	0.68	4.01	-1.85	-10.75	4378.
130	0	0	3.60	1.47	4.18	-1.91	-10.73	4441.
133	0	0	3.58	1.17	4.16	-1.90	-10.81	4418.
178	0	0	3.79	1.06	3.81	-1.89	-10.38	4394.
180	0	0	3.81	1.42	3.67	-1.91	-10.33	4411.
242	0	0	3.82	1.27	3.75	-1.66	-10.20	4424.
111	0	5	3.82	1.31	15.89	-3.46	-16.92	4424.
112	0	10	4.46	1.52	27.45	-4.55	-23.47	4394.
113	0	15	5.48	2.69	39.40	-5.97	-33.65	4366.
114	0	15	5.36	3.89	39.40	-6.20	-33.99	4407.

C2

TABLE C2 (Continued) Test Data in Waterplane Axes
Model-Scale Units
Speed: 15.2 fps (27 knots) R/L: 6.74

Run no	Roll deg	Drift deg	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	Prop RPM
131	0	15	5.47	3.49	39.52	-6.13	-34.01	4394.
136	10	-15	5.97	0.79	-25.44	1.32	12.66	4427.
155	10	-15	6.11	0.52	-26.70	1.05	13.79	4422.
153	10	-10	5.06	-0.64	-13.69	-1.66	-1.05	4415.
152	10	-5	4.02	-0.10	-3.68	-3.66	-9.79	4405.
148	10	0	3.47	2.52	7.05	-5.26	-15.28	4466.
154	10	0	3.47	0.42	6.82	-5.12	-15.49	4374.
149	10	5	3.30	1.21	19.38	-6.62	-21.95	4342.
150	10	10	3.45	2.65	32.69	-7.78	-28.52	4350.
151	10	15	3.57	4.72	46.22	-8.19	-35.60	4326.
139	20	-15	7.82	-5.05	-18.34	-3.80	5.97	4397.
165	20	-15	8.36	-4.58	-19.79	-1.67	9.08	4415.
257	20	-15	8.30	-5.34	-18.26	-3.91	4.59	4476.
164	20	-10	5.93	-2.09	-10.82	-2.72	-2.46	4447.
163	20	-5	4.99	-1.92	2.20	-5.47	-10.07	4395.
159	20	0	3.88	-0.94	13.16	-7.35	-16.60	4369.
255	20	0	3.98	-0.70	12.95	-7.62	-16.50	4432.
160	20	5	3.34	1.16	22.06	-8.87	-23.91	4377.
161	20	10	2.84	2.63	32.99	-10.24	-30.25	4368.
162	20	15	2.48	4.56	46.16	-11.33	-36.42	4325.
256	20	15	2.44	4.96	45.15	-11.62	-35.83	4411.
142	35	-15	9.82	-8.17	-12.04	-5.18	-3.47	4376.
190	35	-15	10.26	-7.53	-13.15	-5.46	-1.20	4389.
189	35	-10	8.28	-7.40	-2.59	-8.02	-8.66	4393.
188	35	-5	5.96	-4.06	7.42	-9.49	-15.43	4389.
184	35	0	5.13	-2.13	20.71	-10.73	-18.32	4388.
185	35	5	4.91	-1.68	39.69	-12.45	-25.21	4396.
191	35	5	4.54	-1.53	37.14	-12.19	-24.48	4330.
186	35	10	2.94	1.62	47.69	-12.06	-24.41	4385.
187	35	15	1.13	2.91	37.36	-12.08	-27.18	4362.

TABLE C3   Test Data in Waterplane Axes
Model-Scale Units
Speed: 5.6 fps (10 knots) R/L: 3.30

Run no	Roll deg	Drift deg	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	Prop RPM
414	-5	-15	1.44	1.73	-8.28	4.36	-13.25	2325.
413	-5	-10	1.76	2.04	-4.01	3.80	-9.69	2324.
412	-5	-5	2.08	0.96	-1.01	3.13	-6.32	2325.
408	-5	0	2.39	0.75	2.02	2.28	-5.51	2331.
409	-5	5	2.71	0.43	4.89	1.35	-5.76	2327.
410	-5	10	2.99	0.52	7.62	0.47	-6.12	2324.
411	-5	15	3.27	0.80	11.14	-0.32	-6.11	2325.
415	-5	15	3.29	0.72	10.88	-0.25	-5.99	2325.
386	0	-15	1.17	1.28	-6.22	2.63	-13.00	2331.
385	0	-10	1.51	2.14	-3.14	1.73	-10.85	2343.
384	0	-5	1.90	0.96	-0.31	1.15	-7.65	2325.
379	0	0	2.20	0.46	2.40	0.40	-6.58	2295.
387	0	0	2.27	0.54	2.45	0.39	-6.79	2328.
381	0	5	2.65	0.40	5.59	-0.53	-6.86	2322.
382	0	10	2.92	0.61	8.32	-1.32	-7.22	2326.
383	0	15	3.23	0.89	11.56	-1.87	-7.15	2324.
403	5	-15	1.01	1.25	-5.65	0.61	-13.77	2331.
402	5	-10	1.40	1.82	-2.63	-0.48	-11.79	2331.
401	5	-5	1.74	0.79	0.21	-1.09	-8.79	2329.
391	5	0	2.10	0.61	3.02	-1.84	-7.75	2331.
404	5	0	2.16	0.48	3.27	-1.82	-7.93	2333.
392	5	5	2.56	0.57	6.18	-2.73	-7.79	2341.
399	5	10	2.93	0.50	9.17	-3.31	-8.28	2327.
400	5	15	3.24	0.81	12.31	-3.89	-8.40	2332.

TABLE C4   Test Data in Waterplane Axes
Model-Scale Units
Speed: 15.2 fps (27 knots)   R/L: 3.30

Run no	Roll deg	Drift deg	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	Prop RPM
529	-35	-15	4.12	-1.10	-29.62	12.66	14.87	4494.
528	-35	-10	5.72	-2.11	-24.16	11.16	9.52	4482.
530	-35	-10	5.73	-0.35	-24.42	10.98	8.08	4485.
527	-35	-5	8.82	-3.93	-32.57	10.18	1.10	4406.
523	-35	0	9.50	-3.42	-15.37	5.87	-5.40	4412.
532	-35	0	8.97	-2.30	-12.68	5.60	-7.04	4439.
524	-35	5	10.31	-4.14	1.10	2.95	-12.16	4426.
525	-35	10	12.55	-5.62	10.89	2.51	-15.12	4463.
526	-35	15	14.08	-6.49	22.57	-0.26	-20.80	4481.
531	-35	15	14.10	-6.25	22.88	-0.48	-21.14	4497.
515	-20	-15	3.58	4.04	-29.56	8.30	12.59	4402.
514	-20	-10	4.60	2.52	-19.64	6.41	6.23	4411.
513	-20	-5	5.57	1.01	-9.18	4.48	-1.47	4414.
509	-20	0	6.79	0.04	-0.06	2.52	-9.49	4416.
510	-20	5	8.09	-1.02	11.08	-0.52	-18.90	4406.
511	-20	10	9.51	0.19	24.74	-4.86	-30.73	4402.
512	-20	15	10.60	2.14	37.15	-9.25	-40.16	4392.
516	-20	15	10.47	1.94	36.75	-9.01	-39.48	4389.
503	-10	-15	3.41	3.72	-33.54	4.27	5.88	4438.
502	-10	-10	3.04	3.48	-17.58	2.98	-1.54	4425.
501	-10	-5	3.22	3.14	-4.47	1.24	-6.77	4418.
483	-10	0	5.29	0.28	4.44	-0.01	-11.86	4409.
504	-10	0	4.49	2.21	5.22	-0.40	-12.26	4415.
498	-10	5	6.29	-0.08	15.36	-2.18	-19.40	4400.
499	-10	10	7.65	0.73	28.28	-4.98	-31.26	4399.
484	-10	15	9.29	3.24	43.76	-9.07	-47.56	4387.
500	-10	15	9.31	3.27	43.99	-9.17	-48.19	4396.
441	0	-15	4.56	2.34	-27.64	0.24	1.99	4445.
440	0	-10	4.11	1.65	-16.48	-0.21	-5.69	4424.
439	0	-5	3.92	0.96	-4.37	-1.41	-12.11	4417.
429	0	0	3.98	1.10	8.04	-3.11	-17.95	4386.
431	0	0	4.05	2.75	8.46	-3.30	-18.31	4499.
432	0	0	4.02	2.32	8.16	-3.07	-18.12	4436.
433	0	0	3.94	2.15	7.88	-3.19	-18.28	4433.
434	0	0	4.05	1.70	7.96	-3.20	-18.08	4407.
436	0	5	4.40	1.63	20.68	-4.54	-24.47	4407.
437	0	10	5.17	2.69	31.74	-5.66	-31.13	4400.
438	0	15	6.48	4.22	45.24	-7.58	-42.69	4366.
442	0	15	6.43	4.41	44.71	-7.49	-42.19	4388.
454	10	-15	6.34	-1.23	-21.47	-1.89	4.79	4430.
453	10	-10	4.65	-0.75	-11.20	-3.05	-12.41	4433.
452	10	-5	3.57	-0.10	-1.94	-4.25	-19.29	4415.
446	10	0	3.29	1.04	10.50	-6.29	-25.50	4423.
447	10	5	3.30	1.82	23.69	-7.59	-30.82	4402.
455	10	5	3.34	1.69	23.21	-7.45	-30.43	4412.
448	10	10	3.38	4.01	36.38	-8.27	-36.49	4410.
449	10	15	3.85	6.72	50.91	-8.66	-44.13	4408.

TABLE C4 (Continued)   Test Data in Waterplane Axes
Model-Scale Units
Speed: 15.2 fps (27 knots)   R/L: 3.30

Run no	Roll deg	Drift deg	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	Prop RPM
464	20	-15	7.49	-6.23	-15.26	-5.98	-2.82	4455.
465	20	-15	7.51	-6.34	-15.73	-6.06	-2.80	4442.
463	20	-10	5.39	-1.72	-7.40	-4.34	-10.79	4449.
462	20	-5	3.85	-1.33	1.83	-6.65	-21.40	4434.
458	20	0	3.10	0.14	14.24	-8.74	-27.07	4438.
459	20	5	2.76	1.42	24.94	-10.15	-31.80	4411.
460	20	10	2.34	3.83	36.60	-11.03	-38.34	4405.
461	20	15	1.98	6.68	48.93	-11.63	-43.06	4392.
475	35	-15	7.44	-7.44	-17.09	-8.43	-14.86	4440.
474	35	-10	5.75	-7.14	-5.02	-10.35	-21.14	4433.
476	35	-10	5.75	-7.24	-4.87	-10.52	-22.45	4433.
473	35	-5	3.90	-4.91	5.24	-10.45	-26.64	4449.
468	35	0	3.26	-3.13	18.20	-11.82	-28.89	4416.
469	35	0	3.32	-2.66	18.54	-11.91	-28.71	4447.
470	35	5	3.00	-0.59	35.48	-12.93	-32.17	4410.
471	35	10	1.72	2.01	47.44	-12.40	-31.77	4404.
472	35	15	.47	5.37	55.83	-11.60	-29.04	4410.

TABLE C5   Test Data in Waterplane Axes
Model-Scale Units
Speed: 5.6 fps (10 knots)   R/L: 6.74
Rudder Deflection Tests

Run no	Roll deg	Rudder deg	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	Prop RPM
322	-20	-30	3.35	-3.06	-6.35	9.96	8.04	2316.
321	-20	-20	3.33	-1.76	-5.18	8.93	5.97	2320.
320	-20	0	3.35	-0.66	-1.33	6.01	-0.39	2313.
323	-20	0	3.29	-0.51	-1.33	6.01	-0.40	2326.
319	-20	20	3.32	-0.77	2.07	3.35	-6.04	2313.
318	-20	30	3.28	-1.05	1.10	3.79	-4.77	2317.
306	0	-30	2.49	-2.70	-5.14	4.08	6.31	2316.
305	0	-20	2.36	-0.95	-3.39	2.94	3.55	2324.
301	0	0	2.18	0.66	1.13	0.19	-3.76	2331.
302	0	0	2.22	0.51	1.11	0.18	-3.77	2317.
303	0	20	2.41	0.08	4.98	-2.31	-10.38	2313.
304	0	30	2.30	-0.82	4.58	-2.01	-9.94	2314.
309	20	-30	2.91	-3.26	-2.36	-1.97	3.30	2320.
310	20	-20	3.01	-2.21	-0.46	-3.27	0.47	2321.
311	20	0	2.63	-0.48	3.84	-6.44	-6.72	2317.
312	20	20	2.57	-0.65	7.23	-8.95	-12.68	2315.
313	20	30	1.92	-0.06	4.47	-6.67	-8.67	2320.
314	20	30	1.79	0.02	4.53	-6.64	-8.76	2316.

C7

TABLE C6 Test Data in Waterplane Axes
Model-Scale Units
Speed: 15.2 fps (27 knots) R/L: 6.74
Rudder Deflection Tests

Run no	Roll deg	Rudder deg	Trim deg	X lb	Y lb	K ft-lb	N ft-lb	Prop RPM
287	-20	-30	6.34	-6.28	-27.64	22.19	32.61	4361.
286	-20	-20	6.20	-2.92	-22.83	18.00	24.76	4377.
283	-20	0	5.61	0.42	-4.90	4.31	-2.61	4394.
288	-20	10	5.40	0.38	5.73	-3.51	-18.61	4357.
284	-20	20	4.39	-1.17	1.79	-3.20	-12.08	4392.
285	-20	30	-1.47	-6.39	0.03	2.71	-4.72	4438.
265	0	-30	3.74	-4.50	-20.02	15.29	29.82	4439.
262	0	-20	3.79	-1.51	-15.36	11.68	21.65	4433.
264	0	-20	3.71	-1.24	-14.13	10.89	19.67	4424.
261	0	0	3.83	1.04	3.50	-1.62	-10.04	4431.
263	0	0	3.84	1.23	4.69	-2.37	-11.74	4437.
269	0	10	4.16	-0.08	13.35	-8.98	-26.57	4416.
266	0	20	2.91	-0.96	9.24	-8.53	-23.19	4420.
268	0	30	-2.43	-5.14	0.60	-0.61	-33.69	4421.
279	20	-30	3.18	-4.32	-12.54	9.85	22.95	4407.
278	20	-20	3.34	-1.61	-5.76	5.29	12.51	4424.
274	20	0	4.14	-1.12	13.48	-7.76	-16.88	4442.
273	20	10	4.55	-2.64	24.59	-15.36	-33.76	4434.
276	20	20	4.76	-5.10	32.48	-21.21	-46.88	4422.
277	20	30	-1.92	-6.78	-3.44	-5.56	-46.32	4417.

COORDINATE TRANSFORMATIONS AND AIR TARES

As stated in the main text, data were acquired in a "balance coordinate system" which was fixed relative to the force and moment dynamometer. The origin of the balance coordinate system was the intersection of the roll axis, which was a horizontal line located 3.95 in. above the baseline at zero trim, and the yaw or drift axis, which was a vertical line passing through the CG at zero trim (at nonzero values of roll and trim, the baseline is not horizontal and the CG does not lie on the drift axis; however the coordinate system retains its original orientation). Since the balance and model rotate together in yaw, the longitudinal (x) axis always passes through the bow of the model; the y axis is horizontal, positive to starboard; the z axis is vertical, positive downward. The coordinate system is shown on Figure D1.

The data were transformed to a parallel coordinate system centered at the CG of the vessel. This coordinate system is referred to as "waterplane axes" because the xy plane remains parallel to the undisturbed water surface (horizontal) regardless of the trim and roll orientation of the craft. This is a convenient system for the analysis and simulation of surface craft maneuvers, as these occur principally in a horizontal plane. The waterplane coordinate system is also shown on Figure A1.

As the axes of the waterplane system are parallel to those of the balance system, the force components are identical relative to both systems. The moments are transformed using the following simple formulas:

$$K_{wp} = K_B + y_o Z_B - z_o Y_B$$

$$N_{wp} = N_B - y_o X_B + x_o Y_B$$

where X_B, Y_B, K_B, N_B are the hydrodynamic axial force, side force, roll moment and yaw moment relative to balance axes; K_{wp} and N_{wp} are the roll and yaw moments relative to waterplane axes; Z_B is the hydrodynamic vertical force component, which is equal to and opposite of the weight of the vessel, and (x_o, y_o, z_o) are the coordinates of the origin of the balance axes system relative to the waterplane system. These coordinates are functions of the trim and roll angles of the model:

$$x_o = a \sin \tau$$

$$y_o = b \sin \phi - a \cos \tau \sin \phi$$

$$z_o = -b \cos \phi + a \cos \tau \cos \phi$$

where τ and ϕ are the trim and roll angles, and a and b are the distance from the pitch pivot to the CG, and the distance from the roll pivot to the

D1

pitch pivot, respectively:

$$a = 0.3125 \text{ ft}$$
$$b = 0.08333 \text{ ft}$$

in model-scale. It was necessary to use a towing gymbal arrangement which had the roll axis located above the pitch axis in order to accommodate the combination of a low pitch pivot height (located on the propeller shaft line at the LCG) with large roll angles and moderate (up to 12°) trim angles.

AIR TARE RESULTS

As described in the main text, the model was towed in the air at a range of speeds, drift angles and roll angles, and measurements were made of the inertial and aerodynamic forces and moments. The following expressions were found to provide good representations of the air tare data, and were used to compute and remove the tares in the subsequent analysis. These expressions correspond to the balance coordinate system, and the tares were removed prior to carrying out the coordinate transformations described above.

R = 32 ft.:

$$X_I = (-0.22396 - 1.09864\beta) \, V^2/1000.$$

$$Y_I = (-64.88 + 0.07918\beta + 0.00504\beta^2)V^2/1000.$$

$$K_I = (-14.474 + 0.067467\beta - 0.042748\phi)V^2/1000.$$

$$N_I = (-1.1136 + 0.087595\beta)V^2/1000.$$

R = 15.67 ft.

$$X_I = (0.77571 - 2.30785\beta)V^2/1000.$$

$$Y_I = (-133.62 + 0.14843\beta + 0.017515\beta^2)V^2/1000.$$

$$K_I = (-29.354 + 0.099273\beta - 0.098035\phi)V^2/1000.$$

$$N_I = (-2.07604 + 0.06290\beta - 0.00161\beta^2)V^2/1000.$$

In the formulas above, β and ϕ are the drift and roll angles in degrees, V is the model speed in ft/sec, and the forces and moments are in model-scale engineering units.

DATA REDUCTION PROCESS

The results of Run 145 will be used to illustrate the data reduction process step by step. All units in the example will be in model-scale. The raw data for Run 145, from Table B2, are as follows:

Run 145
Radius: 32 ft.
Roll: -35°
Drift: -15°
Speed: 15.20 fps.

Trim = 2.56°
X = 3.88 lb
Y = -44.71 lb
K = 9.89 ft. lb.
N = 18.30 ft. lb.
Prop Speed: 4406 RPM

Model Weight = W = 55.42 lb.

The expressions for the tares at the 32 ft radius give the following results:

X_I = 3.76 lb
Y_I = -15.00 lb

K_I = -3.23 ft. lb.
N_I = -0.56 ft. lb.

The measured quantities, less these inertial tares, give the hydrodynamic forces and moments relative to balance axes:

X_B = 3.88 - 3.76 = 0.12 lb

Y_B = -44.71 - (-15.00) = -29.71 lb

K_B = 9.89 - (-3.23) = 13.12 ft. lb.

N_B = 18.30 - (-0.56) = 18.86 ft.lb.

The coordinates of the balance reference point relative to the CG are, at the given values of the roll and trim angles:

x_o = 0.3125 * sin (2.56°) = 0.0140 ft

y_o = 0.08333 * sin (-35°) - 0.3125*cos(2.56°)sin(-35°) = 0.1313 ft

z_o = -0.08333*cos(-35°) + 0.3125*cos(2.56°)cos(-35°) = 0.1875 ft

The transformation equations yield the following results relative to waterplane axes:

X_{wp} = X_B = 0.12 lb

Y_{wp} = Y_B = -29.71 lb

K_{wp} = 13.12 + 0.1313(-55.42) - 0.1875(-29.71) = 11.42 ft. lb.

N_{wp} = 18.86 - 0.1313(0.12) + 0.0140(-29.71) = 18.43 ft. lb.

which correspond to the values for Run 145 in Table C2. In the equations above, the relationship between the weight of the model and the vertical component of hydrodynamic force,

Z_B = -W = -55.42 lb

has been used.

To obtain the nondimensional values given in Table 2, the forces and moments are divided by the displacement (weight) of the model, and the

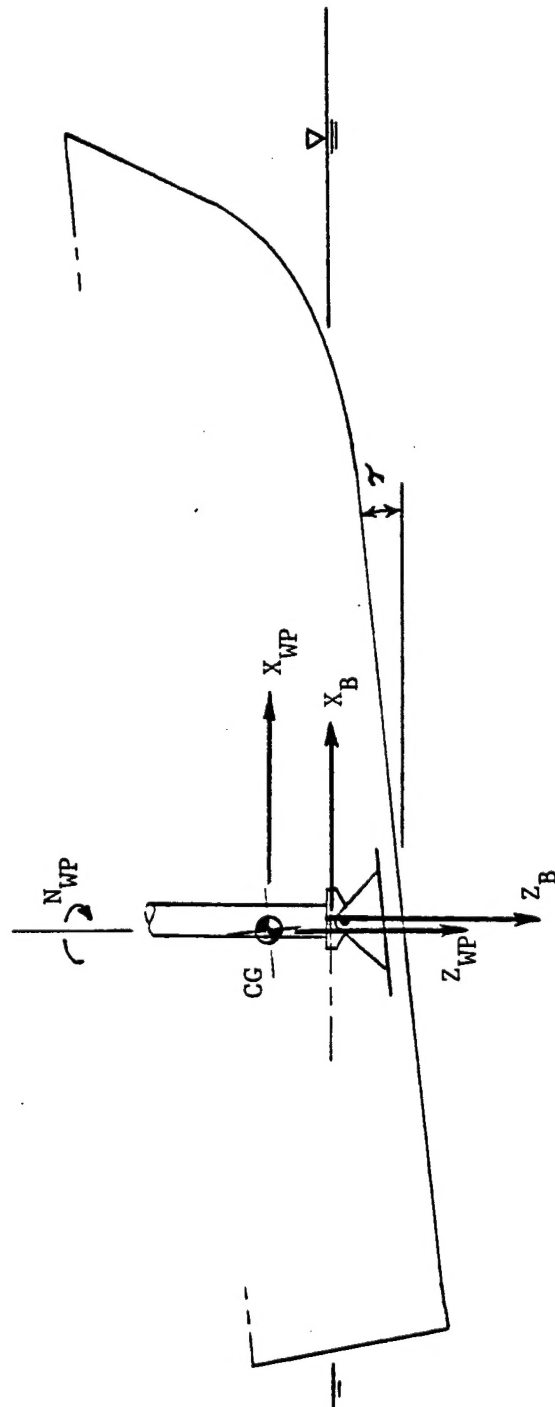product of weight and beam, respectively:

$$X' = 0.12/55.42 = 0.0022$$
$$Y' = -29.71/55.42 = -0.5360$$
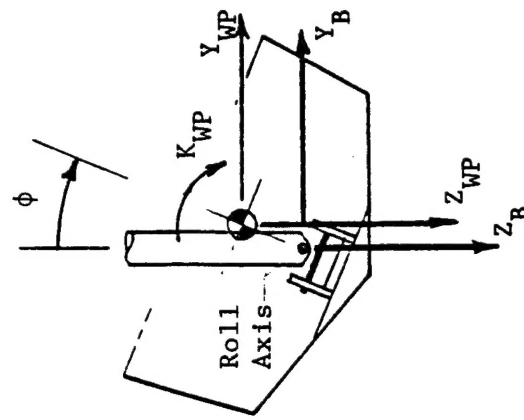$$K' = 11.41/(55.42 * 1.55) = 0.1329$$
$$N' = 18.43/(55.42 * 1.55) = 0.2145$$

The dimensionless value of the propeller speed is obtained by converting RPM to rotations/sec, and then applying the formula given in the text on page 4:

$$n' = (4406/60)* 0.258/15.20 = 1.246$$

TRANSOM ELEVATION
VIEWED FOR TURN TO STARBOARD

STARBOARD PROFILE
VIEWED FROM INSIDE THE CIRCLE

FIGURE D1   Coordinate Systems

D5

TR-2691

APPENDIX E

TABULATION OF WATER TEMPERATURES

Date	Runs	Water Temperature (°F)
7/28	1-54	73.5
7/29	55-118	74.0
7/30	119-165	74.0
8/2	166-227	74.8
8/3	228-288	74.5
8/4	289-361	74.6
8/10	362-415	74.0
8/11	416-485	74.0
8/12	486-557	74.0

E1